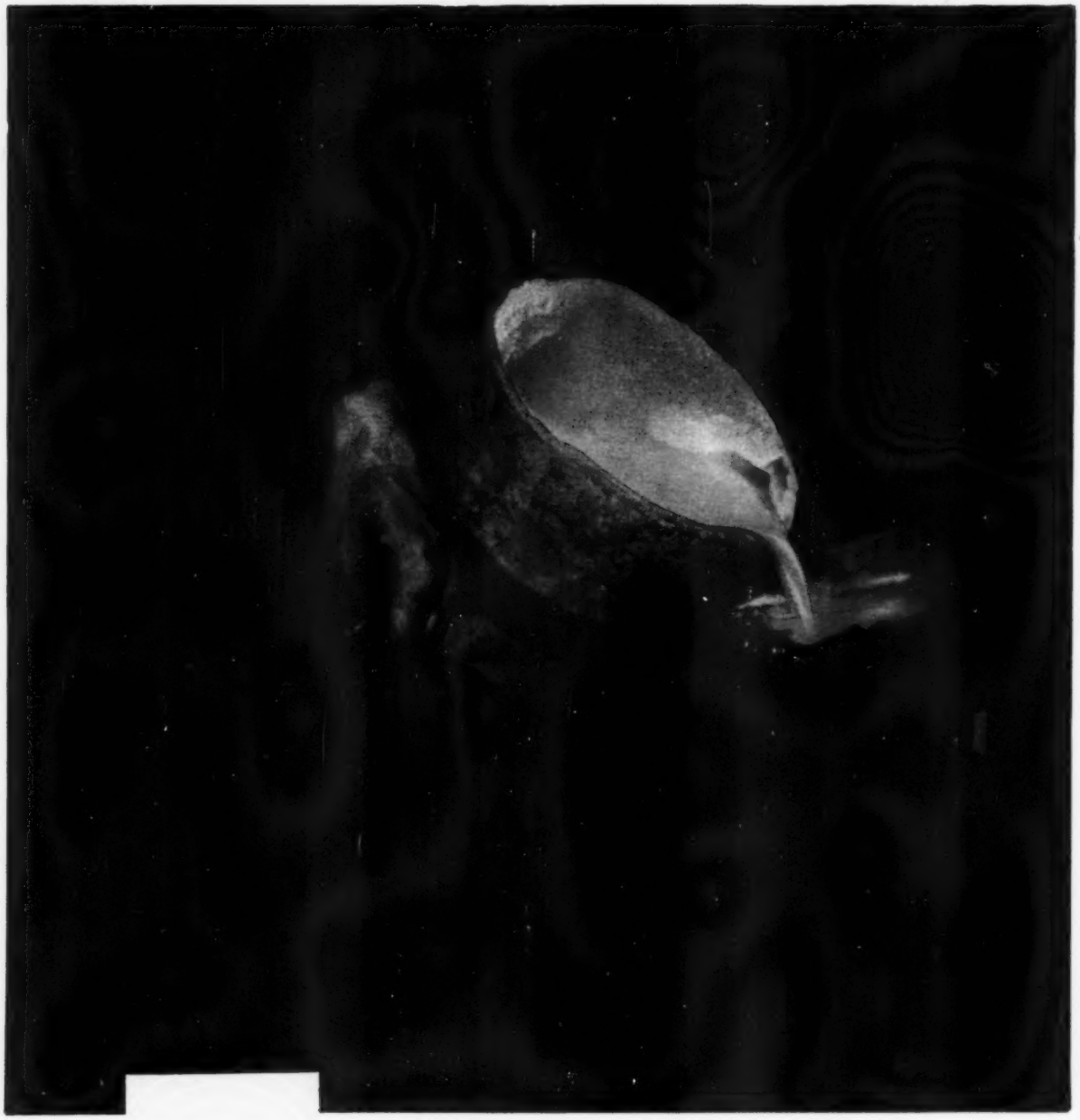
METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 59 No. 356 JUNE, 1959 Monthly: Two Shillings and Sixpence



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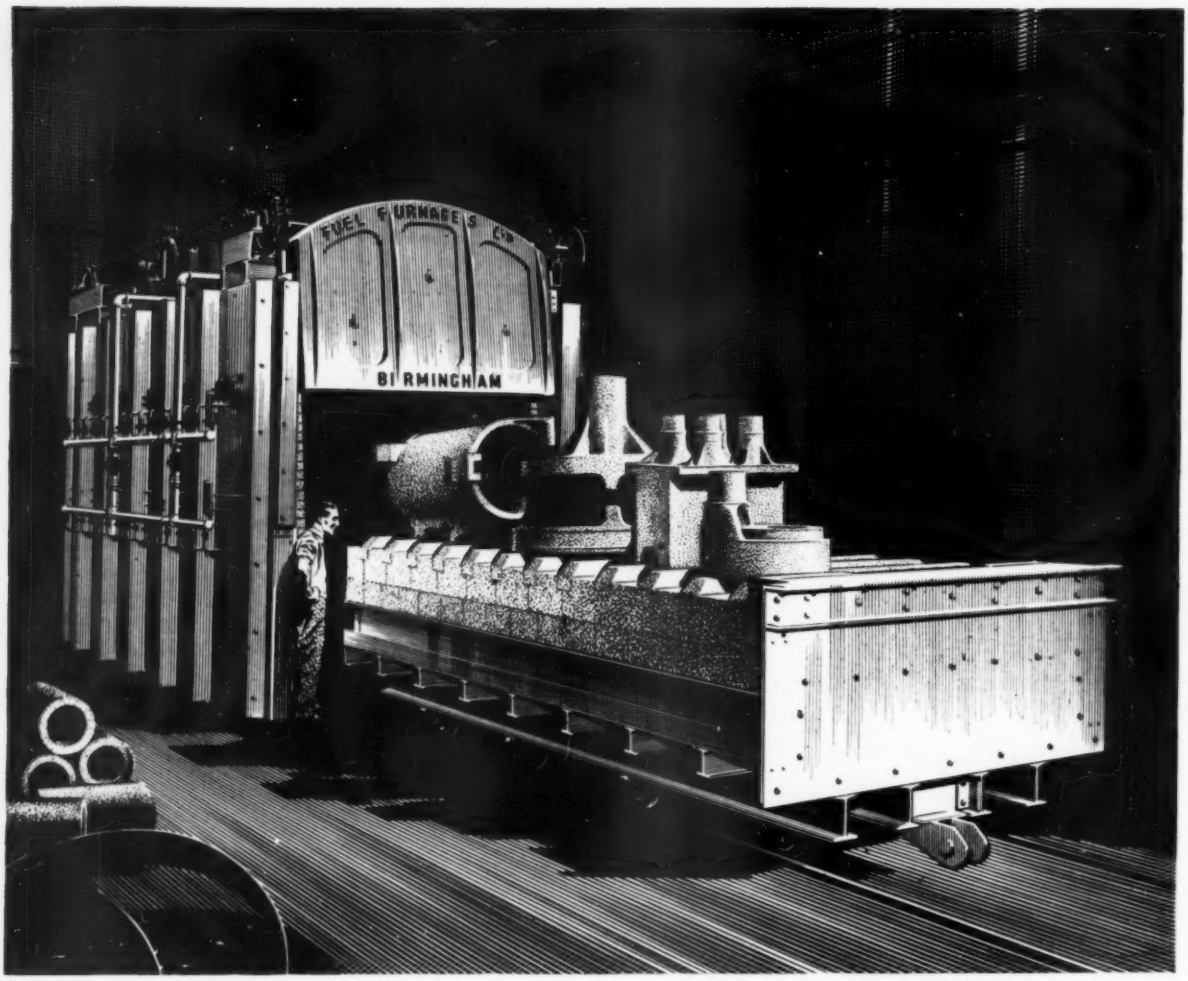

Impression by courtesy of Messrs. A. Hamilton & Sons Ltd.

HEAT TREATMENT **of castings**

Furnaces and Equipment designed and built by

Fuel Furnaces Ltd

SHADY LANE · GREAT BARR · BIRMINGHAM 22A

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top performance thermocouples

now appearing in wide variety

Improved production facilities now make it possible for Honeywell to offer a wider variety of first class pyrometric equipment. Thermocouple assemblies now available for your every need and purpose show these star features:

'Topmost' Accuracy . . . achieved by careful testing and matching of thermocouple wire. Premium grade wires for exceptional accuracy.

'Topmost' Response Speed Unique butt-welded hot junction minimises heat capacity and produces rapid response from smallest temperature change.

'Topmost' Variety . . . metal tube, ceramic tube . . . exposed tip, angle, injection moulding, glass feeder, magnesium oxide filled . . . thermocouples of every specification to measure temperature in ranges from—300°F to 2700°F. All are supplied with suitable mounting attachments for individual needs.

'Topmost' Tolerances for compensating leadwires, ensuring accurate measurement at low cost. Leadwires are available with a wide range of insulating materials, including asbestos over enamel, polythene or plastic over PVC . . . flexible rubber . . . lead sheaths.

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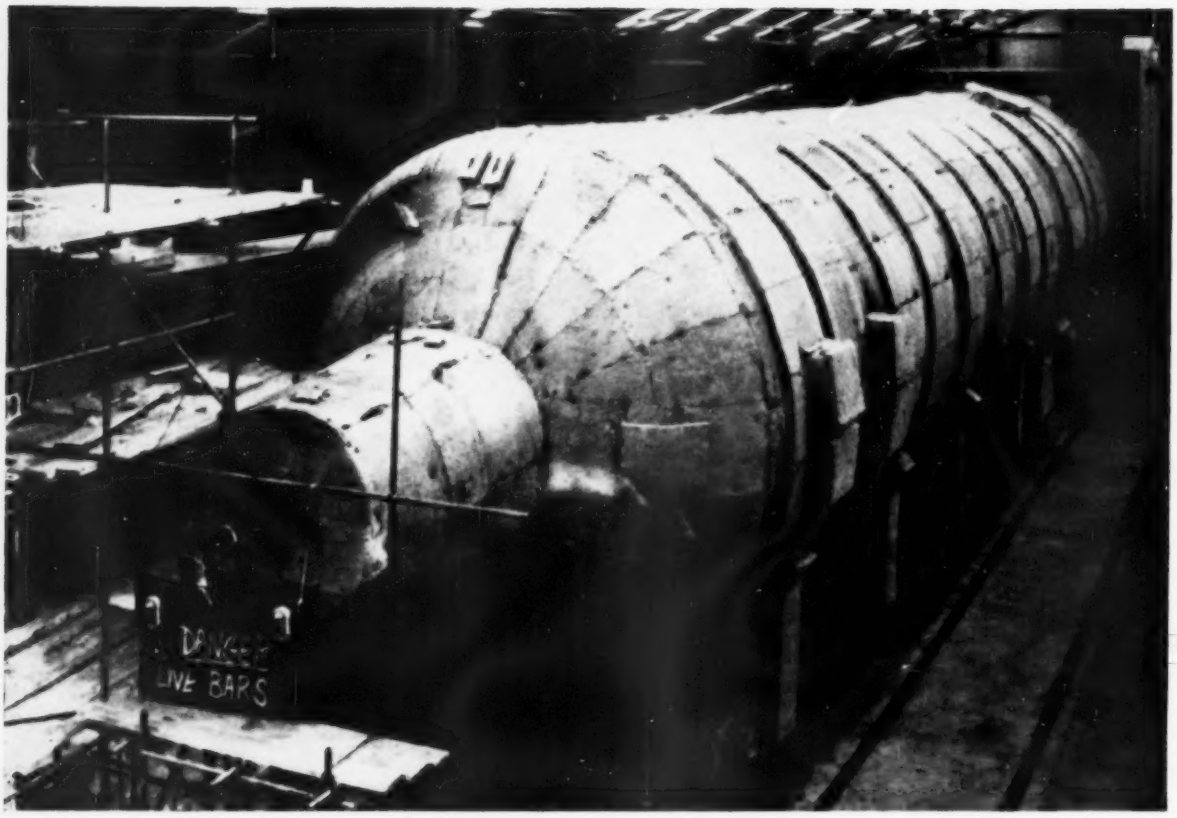

Stress relieving of a heat-exchanger for Bradwell Nuclear Power Station carried out at the Thornaby-on-Tees Works of Messrs. Head Wrightson, Teesdale Ltd.

Stress relieving of LARGE VESSELS

A MODERN TECHNIQUE

Above is an example of this technique. The 95 ft. long heat exchanger is totally covered with Stillite SR10 semi-rigid-slabs and mineral wool mattresses. The heat is applied within the vessel by means of electric resistance elements disposed to give uniform heat. In this instance stress relieving temperature was attained in only *25 hours*, and the soaking temperature maintained.

ADVANTAGES

★ Stress relieving can be carried out on site thus solving the problem of transporting large vessels.

★ Saving in Capital Investment—no outlay required for a large permanent furnace structure.

★ Saving in heating costs. Relieving temperature quickly attained because of the low heat capacity of the enclosing insulation.

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Regd. Trade Mark

Full information upon the application of this technique gladly sent on request.

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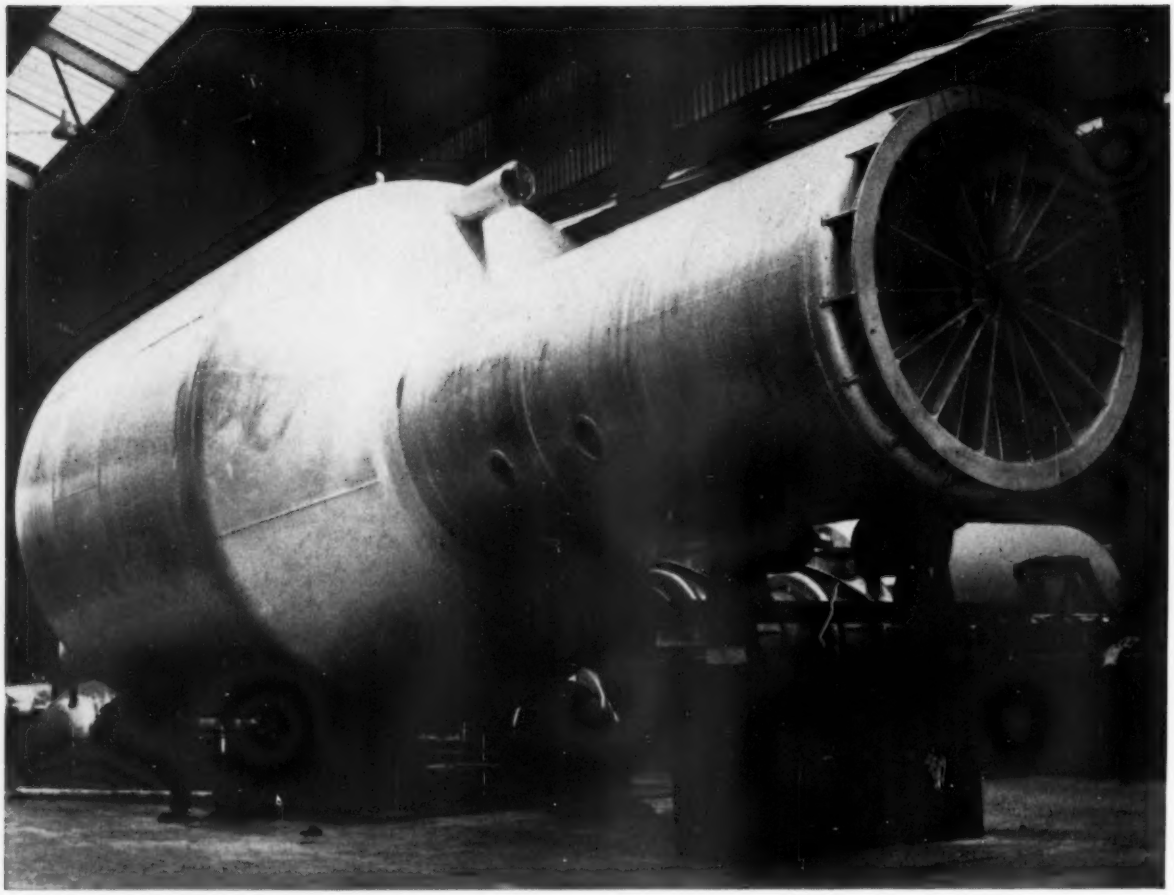

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for MERLIN REACTOR

This Core Tank for a Merlin-type Swimming Pool Reactor was produced by The A.P.V. Co. Ltd, using BA 99.5% purity aluminium plate, inert-gas welded.

In many and often unpublished ways British Aluminium provides technical assistance and material to the Nuclear Energy Industry.

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No. 2 Thermocouple Alloys

We have been making thermocouple alloys at Cheadle for many years. Our experience tells us what people look for and our alloys provide it—stability, constant EMF values and long life.

Different temperature ranges call for different alloy combinations—and we provide them, including 'T1/T2', the only British-made base metal thermocouple for temperatures up to 1100°C. In cases where thermocouple wires are covered by a British Standard we produce them to conform to the Standard.

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Special Advance* wire (60/40 copper-nickel) is for use with copper up to 400°C and with iron up to 900°C. The EMF requirements of these two combinations vary according to individual specifications. Special Advance* wires can be selected in most cases to meet these varying demands within the usual tolerances.

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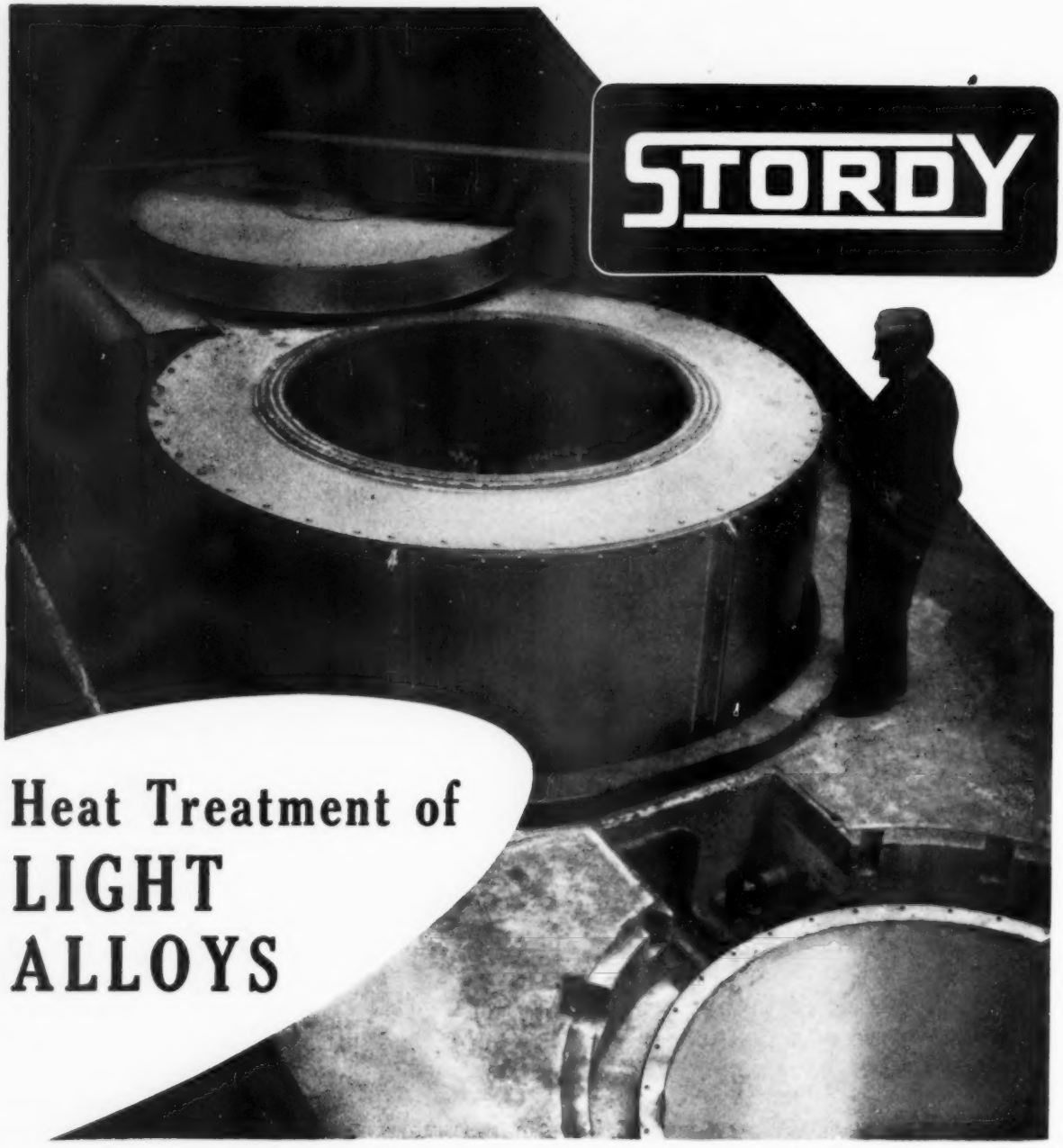
If you are interested in thermocouple alloys, then you may like to have a copy of Data Sheet No. 2, for reference.

*REGD. TRADE MARK

BRITISH DRIVER-HARRIS CO LTD

NICHROME

Cheadle Heath, Stockport, Cheshire



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The furnace illustrated is for the heat treatment of extruded sections—work dimensions 5 ft. diameter by 8 ft. deep.

STORDY ENGINEERING LIMITED
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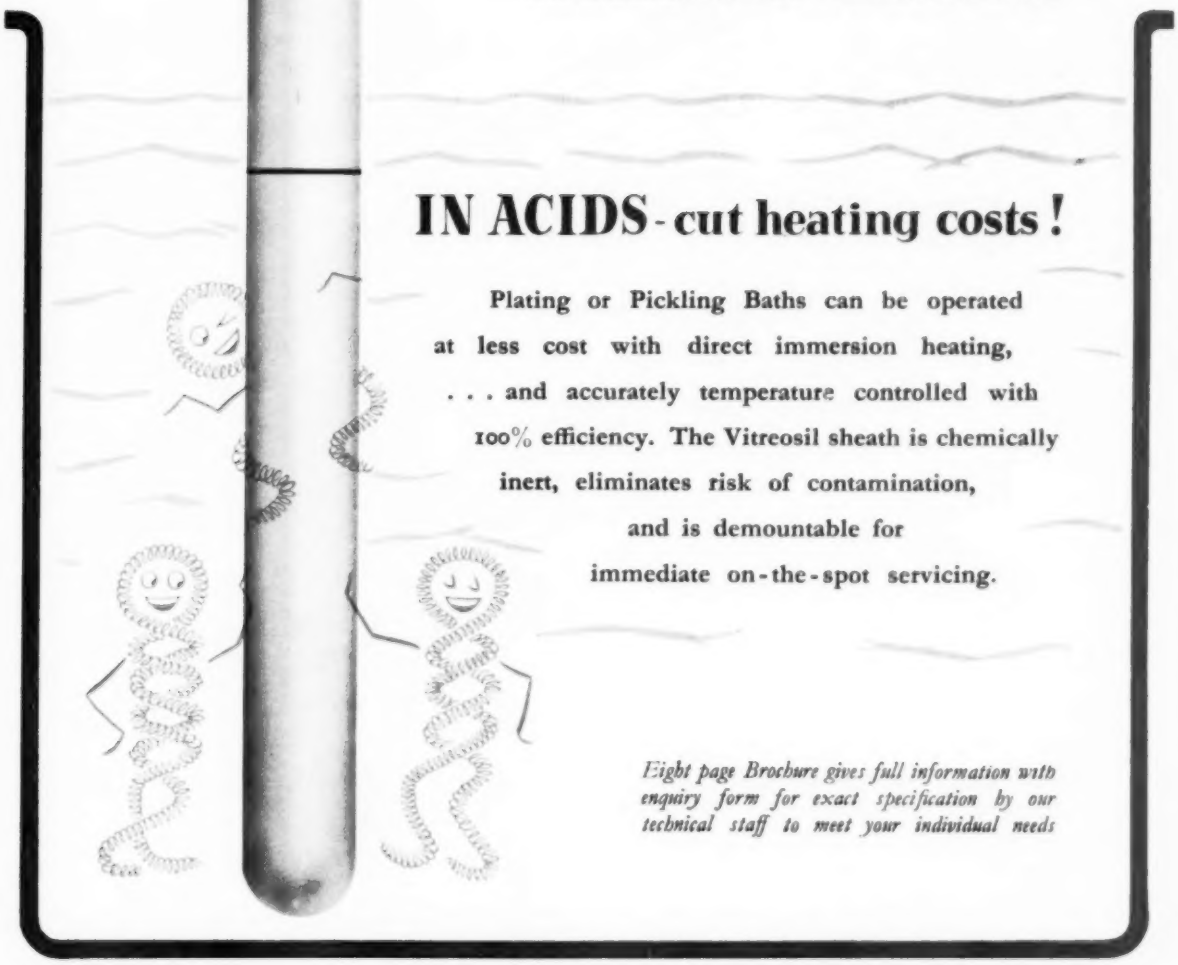

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"What do you call high temperatures?"

"Over 1600° Centigrade.... to stand that and resist—**really** resist—slag attack. **And** do both of these for a long time without cracking."

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"Didn't know you were a refractories expert."

"I'm not—the experts are at Consett Iron Company Limited—they've got a whole range of refractories.... CONSETT 341—that's their number."

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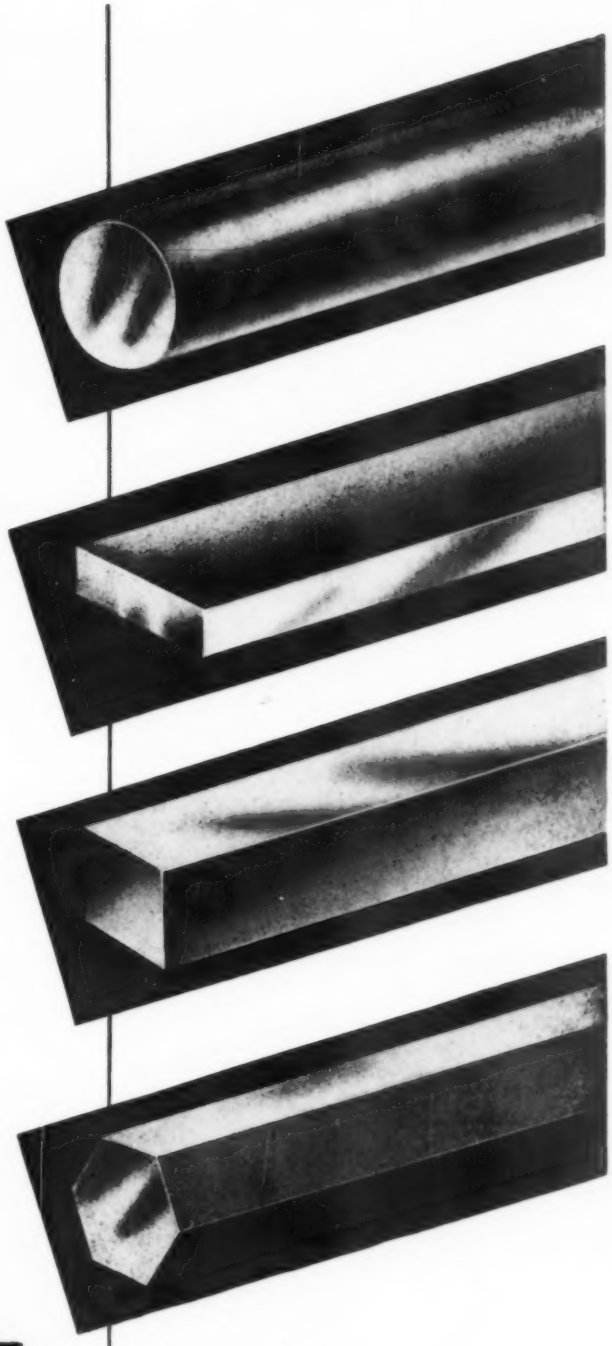

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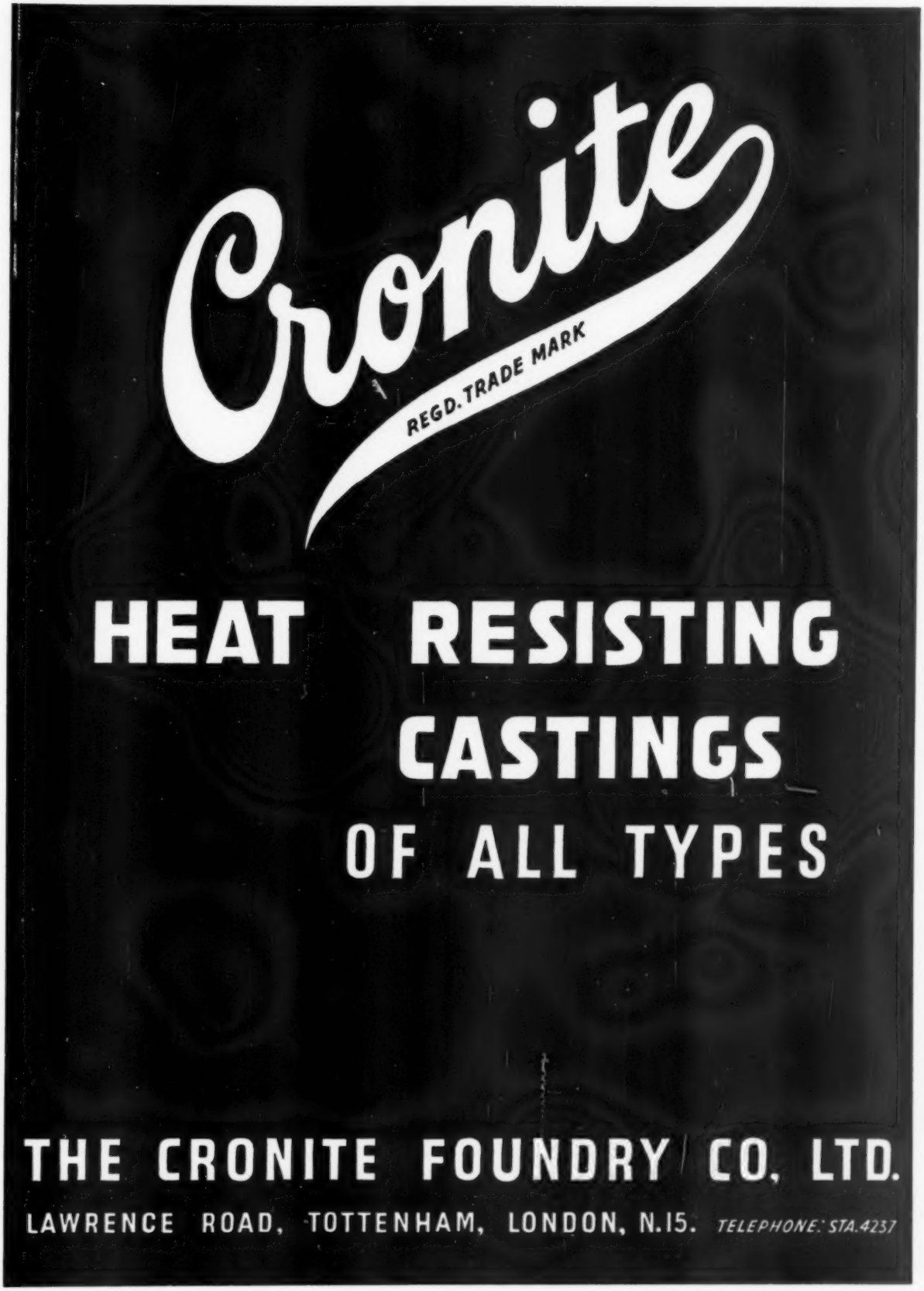
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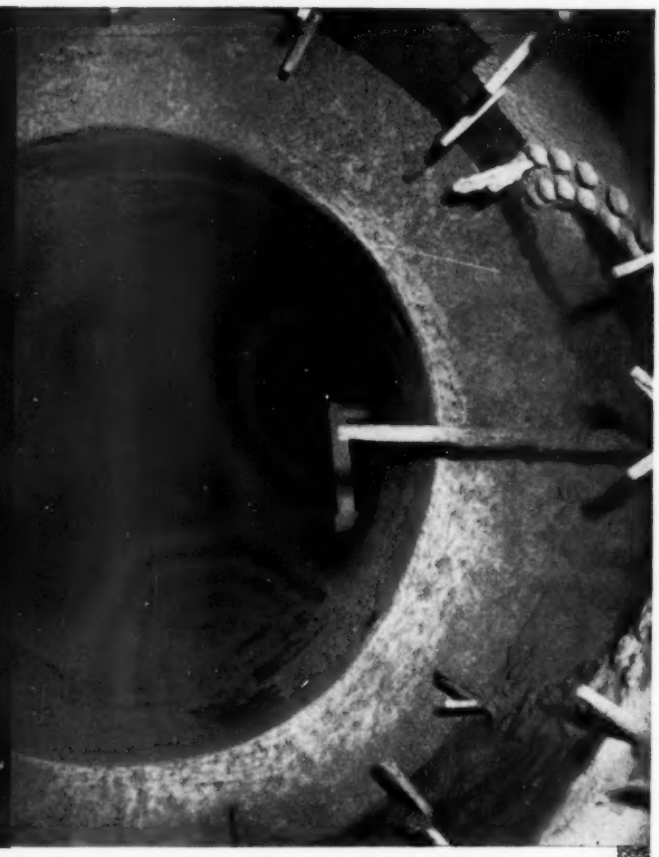

Bustle main of Queen Victoria Blast Furnace showing 'gunned' lining in Tri-Mor Dense 'Guncrete'. (Inside diameter of shell 5 feet. Thickness of 'Guncrete' lining 9 inches).
Photograph by courtesy of the Appleby-Frodingham Steel Co. (Branch of the United Steel Companies Ltd.).

TRI-MOR GRADES

TRI-MOR *Standard Castable*

A medium texture refractory having negligible shrinkage up to 1,350 C. Suitable for casting special shapes or for monolithic structures. Limiting service temperature 1,350 C.

TRI-MOR *High Strength Castable*

A similar refractory to Tri-Mor Standard Castable, but specially developed to have very high mechanical strength over the lower temperature range. Maximum service temperature 1,250 C.

TRI-MOR *High Temperature Castable*

Suitable for face temperatures up to 1,600 C; has an extremely high resistance to thermal shock; used for cast in situ monolithic structures and for pre-cast refractory shapes; can be applied with a cement gun.

TRI-MOR *High Temperature Mouldable*

A plastic refractory for use up to 1,650 C: low shrinkage and a high resistance to spalling. Supplied mixed to the correct consistency for installation.

TRI-MOR *Dense "Guncrete"*

A hydraulic setting refractory with a maximum service temperature of 1,300 C. It has a high resistance to abrasion. Designed for application by cement gun, but can be trowelled.

TRI-MOR *Insulating Castable*

An insulating castable for maximum service temperatures of 1,200 C; low thermal conductivity is its main feature.

TRI-MOR *Insulating "Guncrete"*

Similar to Tri-Mor Insulating Castable but for application by cement gun.

Full details of each grade are available on request.

MORGAN Refractories Ltd

For further information write to: MORGAN REFRACTORIES LTD NESTON, WIRRAL, CHESHIRE. TEL: NESTON 1406 NE 143

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Where even the smallest foreign particle may imperil life, nothing is left to chance. Complex units, such as engine oil coolers which cannot be dismantled for inspection, are therefore radiographically examined to detect accumulations of sludge, metal debris, and carbon particles which would spell danger if they circulated in the engine lubrication system.

For this examination, British Overseas Airways Corporation relies on ILFORD Industrial B X-ray film. Ilford has a reputation for reliability.

Where reliability is all-important

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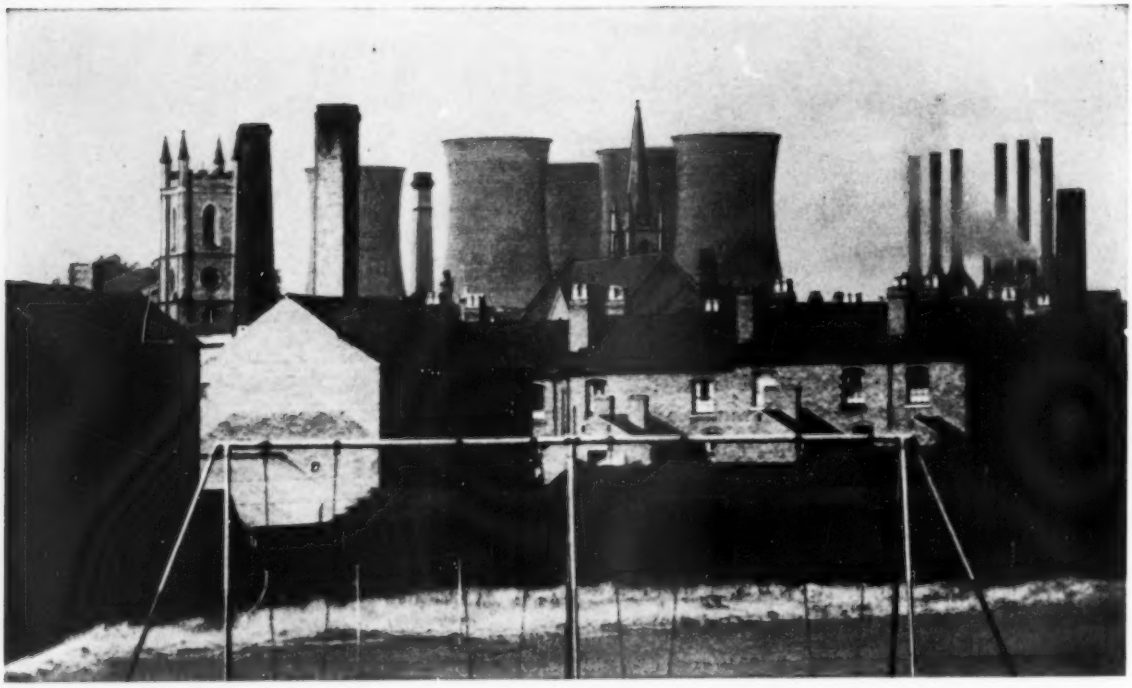

Staffordshire Landscapes

Almost in the shadow of the new power station, factory chimneys and church spires point skywards side by side—silhouetted symbols of material and spiritual welfare.

The children who sometimes play in the foreground have much for which to thank the early Iron founders, whose skill and industry brought to the Black Country prosperity, and a progressive outlook; creating, as the years went by, new industries and cleaner power, better homes and safer playgrounds.

Progress in Staffordshire, bringing almost every major improvement in the technique of iron-founding since 1700, is apparent in the landscape of the County as well as in its products.

For almost a century and a half Pig Iron has been manufactured at Darlaston Iron Works. Today, the most modern methods of metallurgical control of raw materials and the finished product, enables them to supply Pig Iron of consistent uniformity to the most exacting specification.

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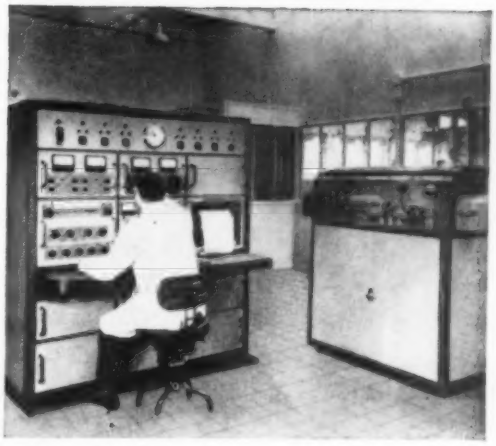
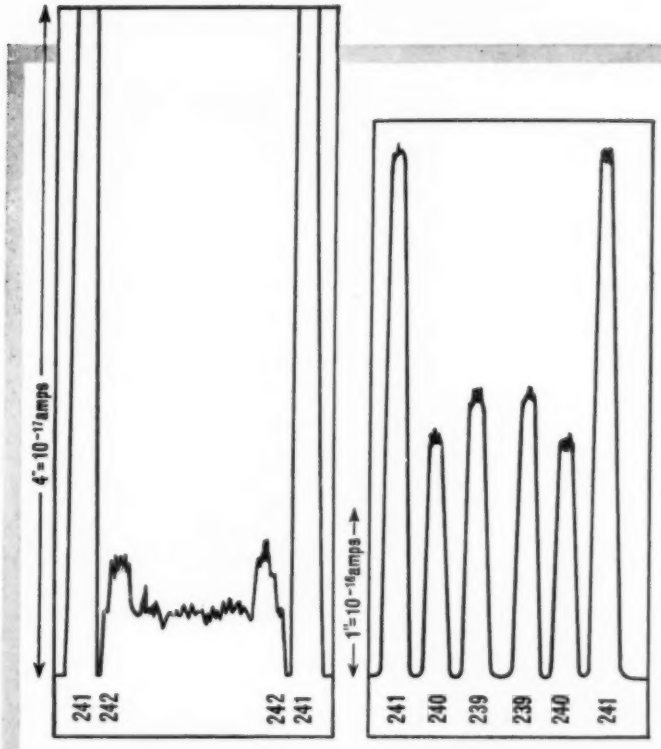
The Metropolitan-Vickers Range of Scientific Equipments includes apparatus for the investigation of metallurgical, chemical and biological problems in research, production or processing. These equipments cover a wide selection of specialised scientific apparatus.

to Scientific Ends



MASS SPECTROMETER TYPE MS5 *An instrument specially designed for the measurement of isotope ratios of inorganic solids by the surface ionisation technique.*



ANALYSIS OF PLUTONIUM

$\frac{m}{e}$	239	240	241	242
% ABUNDANCE	27·20	23·10	49·60	0·072
STANDARD DEVIATION	0·25	0·30	—	0·007

Tabulated results and traces from sample of approximately 10^{-8} grams of plutonium nitrate, using the triple filament technique and the multiplier detector. The standard deviation quoted is taken on 10 measurements.

These results are reproduced by kind permission of the United Kingdom Atomic Energy Authority, Atomic Research Establishment, HARWELL, Didcot, Berks.

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extra Blast Furnace Capacity

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why CARBLOX linings are chosen for Blast Furnaces throughout the world!

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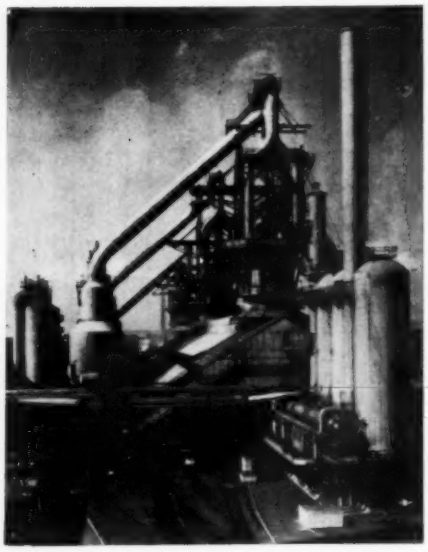

Photograph by courtesy of the Appleby-Frodingham Steel Company, Scunthorpe (branch of the United Steel Companies Limited).

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Blast furnace linings
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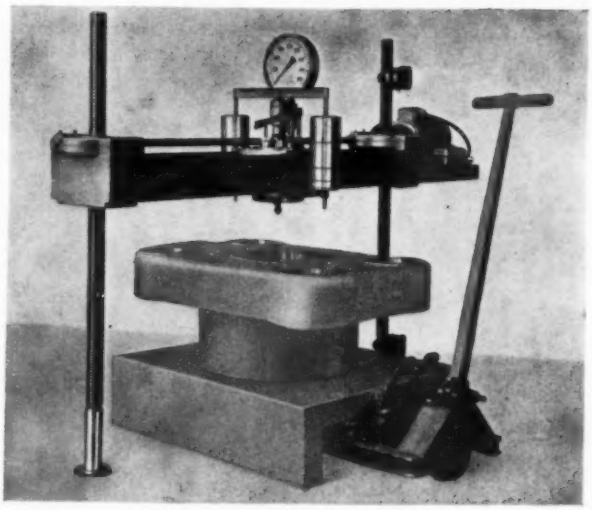

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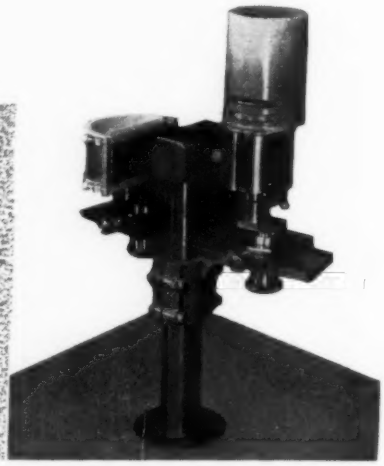
MINIATURE CAMERAS

The Brindley-type camera, miniature General-Purpose camera, and Seeman-Bohlin camera, are specially designed for use with fine-focus generators such as the Hilger Microfocus. Compared with standard cameras, they are small, and give short exposure times and high resolution of pattern.



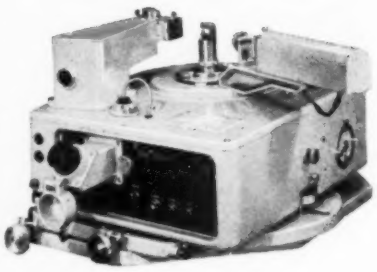
THE MICROFOCUS GENERATOR

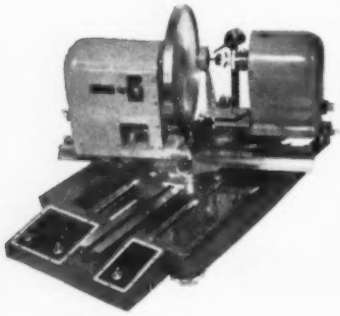
The Microfocus Generator gives an intense line or spot focus for X-ray diffraction work or microradiography. Because of the high intensity of its focus, the Microfocus shortens exposures by as much as seven times.

X-ray diffraction apparatus

THE ENRAF-NONIUS RIMSKY RETIGRAPH

The Rimsky Retigraph uses a flat film to record the reciprocal lattices of any diffracting substance. The radius of the sphere of reflection remains constant, and adjustments are made automatically, once the plane of the reciprocal lattice, and the angle of the X-ray beam normal to this plane, have been chosen.
The Retigraph is made by Enraf-Nonius of Delft.





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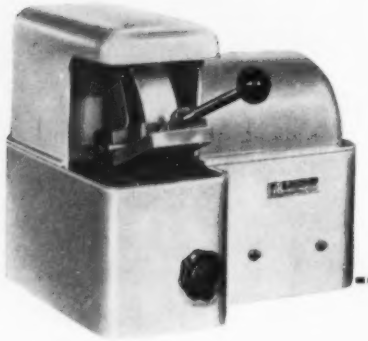

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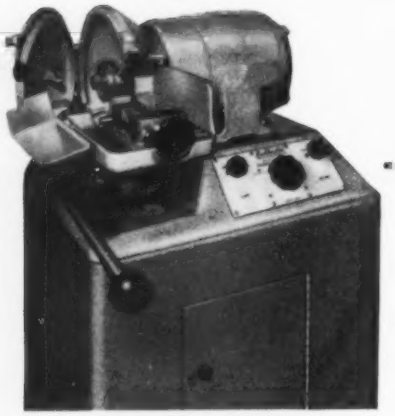

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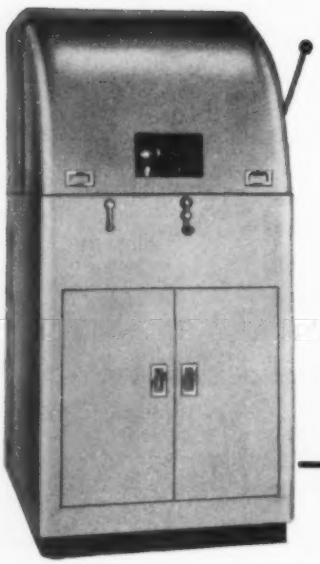

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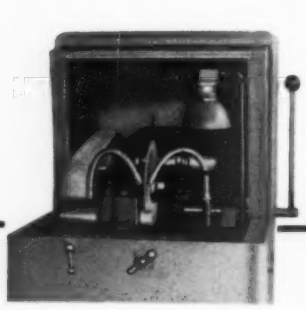

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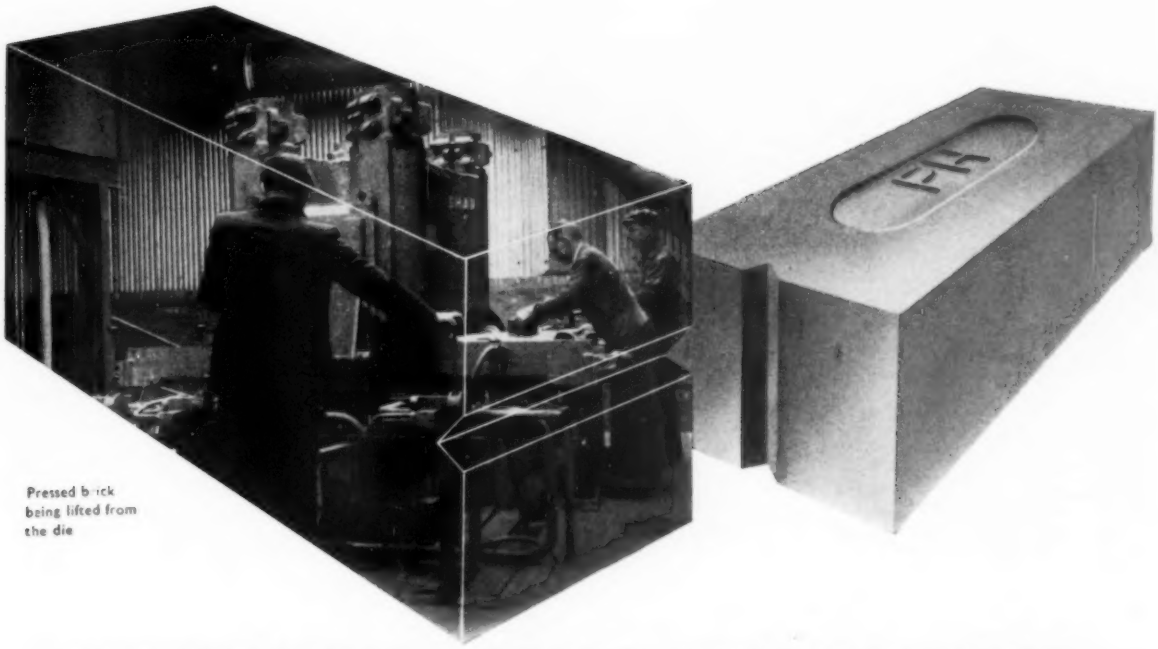

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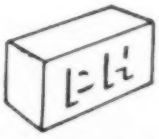

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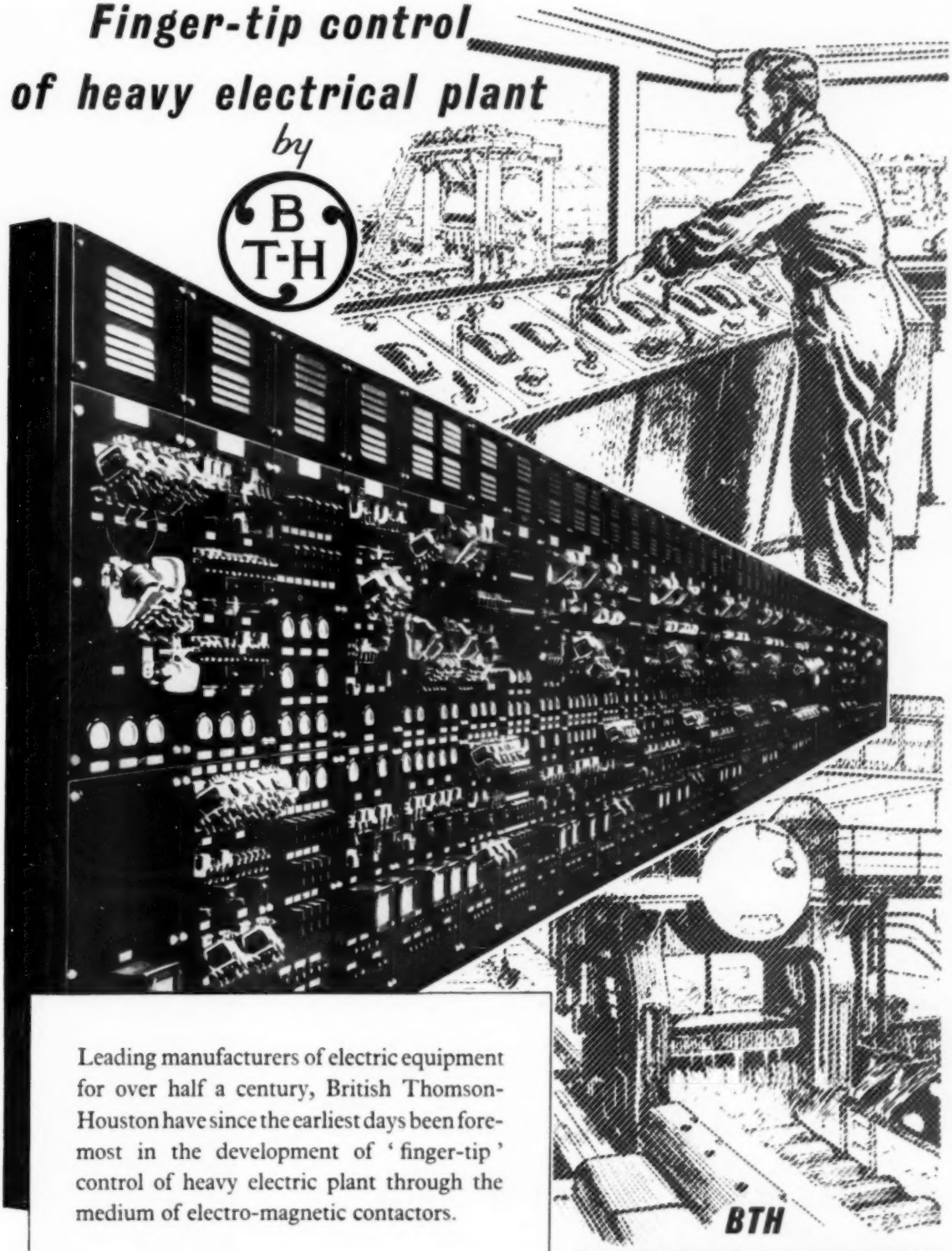

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

JUNE, 1959 Vol. LIX. No. 356

Training Metallurgists

IN his Presidential Address to the Institution of Metallurgists, Professor A. J. Murphy, Principal of the College of Aeronautics at Cranfield, referred at some length to the work of the Institution in the field of metallurgical education. Foremost in the mind of those who founded the Institution fourteen years ago, was the need to advance the status of the metallurgical profession, and successive Councils have realised that in order to attain this objective, adequate standards of admission to the various grades of membership must be maintained. In addition to specifying admission standards, it was desirable that the Institution should take active steps in helping young aspirants for admission to find suitable courses of instruction. The Institution therefore readily accepted an invitation from the Ministry of Education to join with the older metallurgical institutes in the work of the Joint Committee for National Certificates in Metallurgy and has taken an active part in its activities during the last eleven years.

Not unnaturally the National Certificate structure followed the pattern of the longer-established National Certificates in Engineering, but over the years the feeling has grown in the Institution's Council that more emphasis should be placed on basic science and mathematics, even though the change might mean the omission of some of the requirements in the purely metallurgical topics. As Professor Murphy pointed out, advances are liable to be made in metallurgy with disconcerting rapidity, and technological knowledge based merely on a grasp of current practice serves its owner poorly when confronted with an entirely new situation. On the other hand, such new conceptions as high vacuum melting, zone refining, and the effects of irradiation on metals present no fundamental difficulty in acceptance and appreciation to the metallurgist whose training rests on a solid foundation of science. Considerations such as these have been put forward for discussion in the Joint Committee on National Certificates in Metallurgy, and have encountered little opposition, with the result that the Joint Committee is now almost ready to issue the revised scheme, which provides for a Higher National Diploma as well as a Higher National Certificate. The Institution's own revised requirements will also be issued shortly, and although it is appreciated that they will present problems to the technical colleges, it is felt the changes are essentially sound and will lead to a recognition that a member of the Institution is a man whose technology is based on a really sound foundation of science, mathematics and engineering.

On the charge that many technically competent men are distressingly inept in communication by speech and writing, Professor Murphy had to admit that it was not unfounded, but placed the onus fairly and squarely on the shoulders of the schools: "I do not believe that any reasonably intelligent boy who had been properly taught the elements of English grammar and syntax could perpetrate the mangled compositions which are encountered alike in Ph.D. theses and the scripts of technical representatives." By requiring the demonstrations of at least a modest competence in the use of the English language as part of the qualification of a metallurgist, the Institution hopes that the schools will be encouraged to increase their efforts in teaching English for use. "My private opinion," said Professor Murphy, "is that Latin to G.C.E. level yields handsome dividends in adult life in the form of increased confidence and accuracy in English composition, but I wonder how many of my audience I would carry with me on this issue."

Fluent use of the English language is only a part—though a not insignificant one—of the broader aspect of culture. For long enough the view has been held in some quarters that scientists are little removed from barbarians bent upon the destruction of mankind—a view which the development of the atomic bomb did nothing to dispel, in spite of the fact that the demand for it came from outside the scientific world. The timely development of nuclear power production as a by-product, and its likely contribution to the advancement of living standards, particularly in the underdeveloped countries of the world, is ignored, as are the many blessings which science has made available to mankind. Whilst there is much to be said for a broader outlook on the part of scientists, it is equally wrong for the non-scientist to remain ignorant of the scientific developments which are constantly taking place, and any efforts to remedy this situation should be encouraged.

The danger as far as the scientist and technologist are concerned is premature and excessive specialisation, and again Professor Murphy felt that for salvation one must look to the schools, where there should be encouraged an interest in happenings outside the student's specialisation. "Special lecture courses of one hour a week in the liberal arts, isolated from the technological course, make no appreciable impressions on deficiencies in this respect which the student has brought with him to the University or technical college. Somehow time must be found, or regained, in the schools for these opportunities to taste the many savours which go to make a full life." On the other hand, the school curriculum is largely governed by the requirements of those to whom its products next pass, whether they be the universities or employers in commerce and industry. If the former are going to demand extremely high standards in scientific subjects, as an entrance requirement, then the schools must of necessity encourage specialisation to an extent which many think to be undesirable at such an early stage. The demand for university places is now so great, however, that some specialisation is necessary in order to assess the suitability of a given student for admission to a course in science or technology. Furthermore, the desirability of a technologist's training being based on sound scientific knowledge makes it necessary for the foundations of that knowledge to be laid at school, with the possible alternative of a longer university course.

Personal News

DR. W. STEVEN, Superintendent of the Development and Research Department Laboratory of The Mond Nickel Co. Ltd., in Birmingham has been transferred to the Development and Research Division of The International Nickel Co., Inc., New York, as Director of Research. He has also been elected an Assistant Vice-President of that Company. He is succeeded in Birmingham by DR. G. L. J. BAILEY, formerly Superintendent of the Platinum Metals Research Laboratory of Mond Nickel's Development and Research Department at Acton. DR. W. BETTERIDGE, Development Officer at the London headquarters of the Company has been appointed Superintendent at Acton.

MR. F. T. BAGNALL, Immediate Past-President of The Electric Steel Makers' Guild is at present on a visit to the United States, during which he will attend, at the invitation of the President, the Annual Meeting of the corresponding organisation in America, the Electric Metal Makers' Guild, Inc.

MR. T. A. STONE, Canadian Ambassador to the Netherlands from 1952 until the end of last year, has been appointed Special Assistant to the President of The International Nickel Company of Canada, Ltd. He will also serve as Special Assistant to the President of the United States Subsidiary, The International Nickel Co., Inc., and will have his headquarters in New York City.

MR. W. E. HALE has resigned his position as Chairman and Director of Hale & Hale (Tipton), Ltd., on the grounds of ill-health, and the Board have nominated him to be President of the Company, subject to confirmation by the shareholders at the next Annual General Meeting. He is succeeded as Chairman of the Company and Subsidiaries by MR. R. C. LEPPINGTON, whose position as Vice-Chairman is now held by MR. W. CLARKSON. MR. J. A. WYLDE has been appointed Managing Director of Hale & Hale (Tipton), Ltd., and MR. T. COE takes up up an appointment as Managing Director of the Subsidiary Companies whilst retaining his post as Director and Secretary.

PROFESSOR F. C. THOMPSON retires this year from the Chair of Metallurgy in the Victoria University of Manchester, an appointment which he has held for almost forty years. He is succeeded by DR. C. R. TOTTLE, Deputy Director and Head of the Reactor Division at the Dounreay Experimental Reactor Establishment of the United Kingdom Atomic Energy Authority.

ATOMIC POWER CONSTRUCTIONS, LTD., have appointed MR. H. E. DIXON as Head of Research and Development and DR. A. G. H. COOMBS as Deputy Head of Laboratories at Heston. MR. D. C. F. LUM succeeds Mr. Dixon as Chief Metallurgist, and will normally be located at Head Office.

MR. F. H. POOLE has been appointed Joint Managing Director with the Chairman Mr. W. Eva, of Eva Brothers, Ltd., forgemasters and engineers. Mr. Poole was Works Manager, being elected a Director in 1950 and Deputy Chairman in 1954.

AT the Annual General Meeting held on April 14th, SIR RONALD W. MATTHEWS, D.L., J.P., has been succeeded as Chairman of General Refractories, Ltd., by MR. R. A. KIRBY, J.P. Mr. Kirby joined General Refractories, Ltd., in 1928, becoming a Director the following year, and was appointed Managing Director in 1938. MR. J. GREGORY, Production Director, takes up the position of Managing Director this month. MR. B. EICHLER, Director of Research, has been appointed to the Board, and MR. A. MCKENDRICK, M.B.E., M.C. has retired.

DR. R. T. PARKER has been appointed Head of Aluminium Laboratories, Ltd.'s Banbury and Geneva Offices in succession to MR. R. D. HAMER. Dr. Parker joined the Aluminium, Ltd., Group in 1938 and transferred to Aluminium Laboratories, Ltd., in 1946 as Head of the Metallurgical Division : In 1950 he became Director of Research at the Banbury laboratories.

MR. D. N. GIFFORD, Commercial Manager, has been appointed a Director of Birlec-Efco (Melting), Ltd.

FOLLOWING a Board meeting of The United Steel Cos., Ltd., held in London on May 20th, it was announced that MR. A. J. PEECH had been appointed Deputy-Chairman. This appointment is additional to his position as General Managing Director of the Company.

MR. J. C. MILNER, Director and Vice-President of Aluminium Union, Ltd., has retired from the Company's service. MR. R. A. GENTLES, has succeeded Mr. Milner as Director and Vice-President in charge of the Company's London Office.

MR. W. HACKETT, JNR., and MR. R. D. YOUNG, have been appointed Assistant Managing Directors of Tube Investments, Ltd.

MR. J. BELL, Chairman of the Local Board of Armstrong Whitworth (Metal Industries), Ltd., and a member of the Joint Iron Council, visited Canada last month to meet industrialists and steel manufacturers. At present there is no major steel roll producing plant in Canada, and most rolls are imported from the United States. Armstrong Whitworth produce a comprehensive range of steel rolls, and the purpose of Mr. Bell's tour is to familiarise Canadian Manufacturers with European research, development and production methods, with particular reference to iron and steel rolls.

IT is announced by John Bedford & Sons, Ltd., Sheffield, that MR. C. E. HOLMSTROM, J.P., has been invited to join the Company's Board. Mr. Holmstrom is Chairman of Shepcote Lane Rolling Mills, Ltd., and a Director of Firth-Vickers Stainless Steels, Ltd.

MR. G. E. ROBERTSON, has been appointed Manager, Sales and Contracts, of the Meter, Relay and Instrument Division, and MR. P. G. BEVIS has been appointed Manager, Sales and Contracts, Relay Department of The English Electric Co., Ltd., Stafford.

Obituary

WE regret to record the death of the following :

MR. I. HEATHCOTE, Technical Sales Representative of Brayshaw Furnaces, Ltd., Manchester. Mr. Heathcote joined the outside Sales Staff of Brayshaws in 1955, and was well known in engineering circles in Sheffield, Rotherham and North East England.

MR. G. BENNETT, Manager of the Liverpool factories of Automatic Telephone & Electric Co., Ltd. Mr. Bennett, who was aged 45, started his career in telecommunications with the British Post Office. He joined A.T.E. in 1945 after leaving the Royal Corps of Signals, in which he held the rank of Lieut.-Colonel.

Electric Arc Steelmaking Using Hot Metal Process

Pre-refining Technique Developed at Brymbo

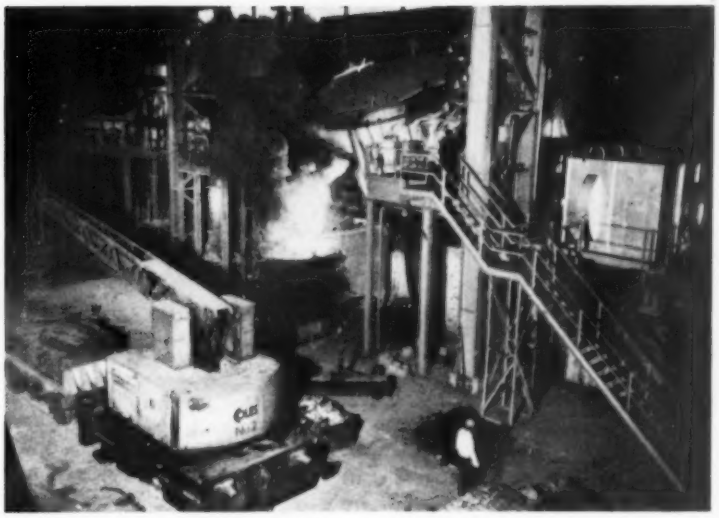


Fig. 1.—Tapping metal from the pre-refining furnace.

A method of pre-refining molten pig iron in such a way that the silicon and phosphorus are removed without excessive reduction of carbon is the basis of a new electric melting shop using a hot-metal process at Brymbo Steel Works, Ltd. An account of the background history and of the process itself is presented here; it is hoped to publish a description of the new melting shop in the July issue.

IN the course of its long history, dating back to 1798, the iron and steel works at Brymbo, near Wrexham, has pioneered many new processes. In 1884 the first basic open hearth steel furnace in the British Isles went into production there, and in 1894 the first by-product ovens to produce coke for use entirely in the blast furnace were commissioned. Between 1899 and 1905 the Bertrand-Thiel steelmaking process was practised: this process, now obsolete, was one of the forerunners of pre-refining as practised today. In 1912 experiments with refrigerated air for the blast furnace were made, and carbon was used as a hearth lining material: this was a complete innovation at that time.

In June 1931, the works were closed down during the world-wide slump and remained closed until 1933, when Sir Henry Robertson succeeded in forming a new company known as the Brymbo Steel (Successors) Co., Ltd. It became obvious in 1937 that Brymbo could not exist on the usual 'bread and butter' steels, and production was concentrated on low alloy steels, among them 4% silicon steel—which had been a Brymbo speciality since 1906—and silico-manganese spring steel.

Electric Arc Furnace Melting

During the early months of 1939 work was commenced on a new melting shop for the production of aircraft steels, and a 7-ton basic electric arc furnace was commissioned in February, 1940. Later in 1940 the works came under the technical control of Messrs. Thos. Firth & John Brown, Ltd., and three additional 15-ton basic arc furnaces were installed. At the end of the war it was realised that the old open hearth shop was rapidly becoming obsolete and uneconomical, but by deepening the baths and other modifications, a substantial increase in output was obtained, and it is only a matter of weeks since the plant ceased to operate and the Brymbo works became an all-electric steelmaking unit. The post-war years have also seen the capacity of the 15-ton arc furnaces doubled by bath deepening, and the use of oxygen for decarburisation became a regular production feature, saving time, electric power and electrodes.

Difficulties in the production of silicon and silico-manganese steels in the open hearth furnace, due to the amount of slag necessary to deal with the large and variable quantities of unwanted elements in the blast furnace metal, were overcome when, in co-operation with the British Iron and Steel Research Association during the period 1948–51, the use of an oxygen lance for desiliconising blast furnace metal was established as a regular production feature. This development has brought relief to many open hearth plant managers and is widely used today.

Oxygen-Electric Steelmaking

By 1953 this process had been thoroughly explored and it was clear that not only could silicon be removed from the blast furnace metal, but by combining the use of oxygen and basic oxides it was possible to reduce considerably the phosphorus content, also without serious loss of carbon. This again was a development of considerable importance to the steel industry, for it meant that the 'hot-metal' process could now be extended to the electric furnace, which had hitherto been mainly regarded as a scrap melter for reasons which will be discussed later.

The end of the open hearth plant was now plainly in sight, and a decision to develop the oxygen-electric hot metal process almost clinched. Owing to the political changes resulting from nationalisation, however, the scheme had to be shelved until the G.K.N. Group re-

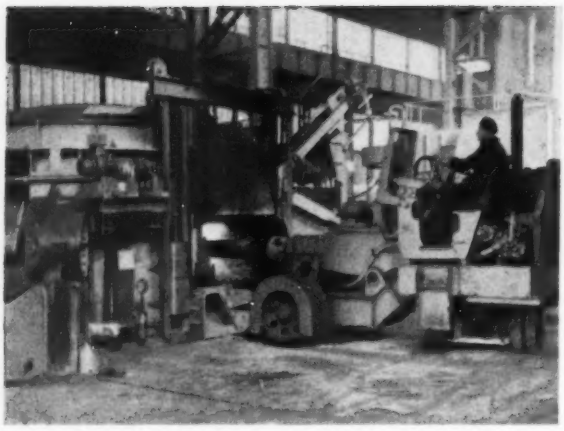


Fig. 2.—Charging scrap into the pre-refining furnace.

acquired the Brymbo works in 1955. The way was then clear for the next step forward, which took the form of a new £2 million all-electric steel plant operating the hot metal process which recently commenced production and superseded the open hearth plant. This development makes Brymbo one of the two biggest all-electric steelworks in Britain, and the only one working a hot-metal process.

The Necessity for Pre-refining

The reason why blast furnace metal must receive a pre-refining treatment before it enters the electric furnace is that the latter is not well adapted to undertake the refining of molten iron. Unlike the open hearth furnace, which has an extensive system of flues and ducts connecting the hearth with the outer atmosphere and enabling a constantly oxidising atmosphere to be maintained within the hearth, the electric arc furnace treats the metal in a more or less sealed-off chamber, the atmosphere of which can, in fact, be made reducing if so desired. The result is that to refine silicon, phosphorus and more than about 1% of carbon from molten metal in an electric arc furnace is for all practical purposes impossible. The action is very slow and the quantity of basic slag which is necessary to 'fix' the phosphorus causes severe wear on the electrodes. High consumption of electric power, the most expensive item in electric furnace practice, makes the entire operation uneconomic.

Methods of Pre-refining

A common practice on the Continent (and at one or two places in Britain) which enables the electric steelmaker to get around this difficulty, is to use the arc furnace as part of a duplex steelmaking plant. The blast-furnace metal is first blown in a basic Bessemer converter to remove *all* its metalloid impurities, and the "blown metal" is then transferred to the arc furnace for deoxidising and finishing. This technique is, however, open to a number of objections, viz :

(*i*) If the metal is to be blown in the basic-Bessemer converter and reach a reasonably high temperature finally, it must initially contain some 1·5–2% phosphorus.

(*ii*) If the phosphorus is to be removed efficiently from the metal, all the carbon must first be blown out, as dephosphorisation follows decarburisation in the basic converter. A low-carbon metal has unavoidably a high melting point, and is difficult to handle.

(*iii*) Because the carbon is removed almost wholly in the basic converter, the resulting slag after dephosphorisation is high in iron oxide. The metallic recovery in the duplex process therefore always tends to be rather low.

Now the Brymbo blast furnace metal normally contains only about 0·6–0·8% phosphorus ; too much for the electric arc furnace to cope with, but at the same time nothing like enough to enable the basic converter to blow the metal to a workable temperature ; so from the start the ordinary Continental-type duplex process was out. In its place the management at Brymbo have developed a process of pre-refining with oxygen. This is notably superior to the ordinary duplex arrangement because it removes the silicon and phosphorus from the metal *before* decarburisation ; so that—

(*a*) The blown metal still retains a fairly low melting point, making it easier to handle.

(*b*) Enough carbon is left in the metal to make final decarburisation in the arc furnace (using the oxygen lance) simple and rapid.

(*c*) The iron oxide content of the pre-refining slag can be kept at quite a low level, making the overall metallic recovery high.

Design of the Pre-refining Furnace

The pre-refining unit now in operation at Brymbo was built for the company by The Wellman Smith Owen Engineering Corporation Ltd., and is shown in Figs 1–4. Essentially, it consists of a deep, saucer-shaped hearth, 16 ft. in diameter, resting on rockers and rollers so that it can be tilted, the axis of tilt being so arranged that at all angles the water-cooled duct for removing fume and products of combustion remains in full operation. This deep hearth has a basic (dolomite) lining and a high-alumina brick roof. The design is covered by several patents, and was decided upon as a result of a number of experiments in the open hearth and electric furnaces which showed that when blast furnace metal of this analysis is treated with oxygen two main problems have

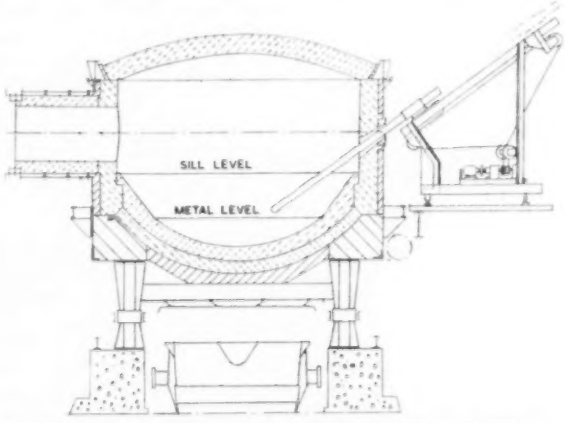


Fig. 3.—Section through pre-refining furnace showing (left) central water-cooled furnace off-take, and (right) water-cooled lance.

to be tackled, the removal of fume, and the control of the foaming and frothing of the slag during the reaction.

For fume removal, therefore, a wide water-cooled duct is provided which connects with a flue leading to a powerful fan and a chimney. A fume filtering plant will be installed at a later date to stop atmospheric pollution. To control the foaming slag, the hearth was deliberately made deep, as shown, and in addition oil burners are incorporated mounted tangentially in the walls. These burners incorporate an unusual and novel feature, the air supply for them being passed under the furnace hearth to obtain a degree of pre-heat (and cool the hearth at the same time), and in addition this air supply can be enriched with oxygen tapped off the main supply.

Injection of Oxygen and Lime

Oxygen for the pre-refining operation is injected into the metal through water-cooled "jets" or "lances". One of these protrudes into the furnace on the axis of tilt and so can operate while the furnace is tilted, the other must be withdrawn; this is shortly to be replaced by a vertical lance through the roof, which can also be used for injecting lime. These lances can inject oxygen at a rate of up to 800 cu. ft./min. Oxygen may also be introduced into the metal through "dry" lances, pushed over the working door sill.

A particular feature of the Brymbo pre-refining furnace, which again is probably unique in Great Britain, is the employment of fluidised powdered lime and limestone, fed into the metal along with the stream of oxygen

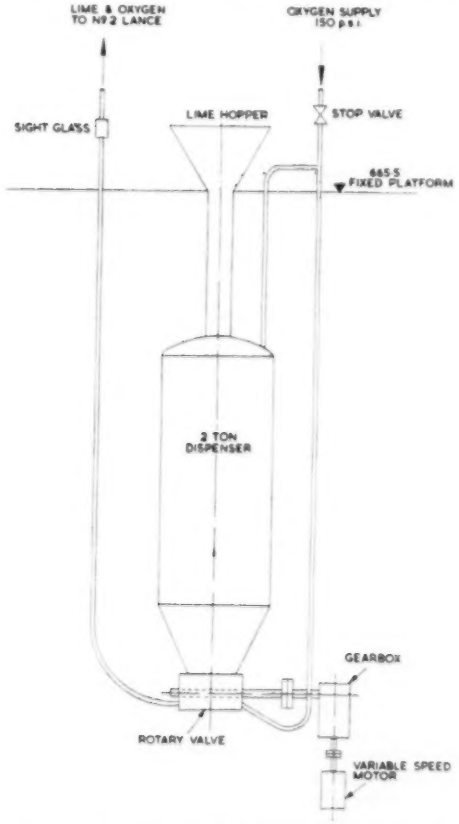


Fig. 5.—Arrangement of dispensing equipment.

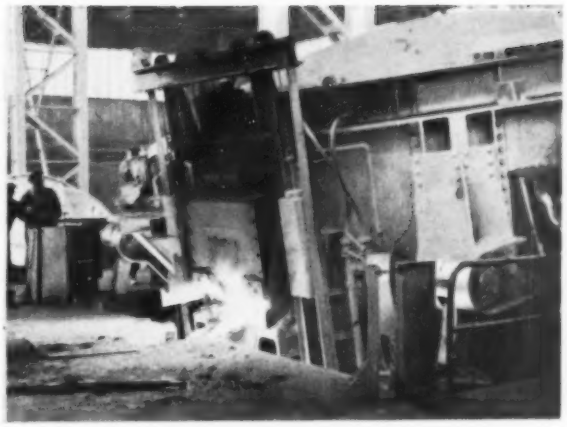


Fig. 4.—Slagging-off the pre-refining furnace.

to form the slag. Tests indicate that this is a far more effective way of making a fluid and reactive basic slag than relying entirely on the "fluxing-down" of solid material thrown on to the metal surface. The powdered material is introduced into the stream of oxygen gas by means of the special "dispenser," designed and built by the Yorkshire Engineering & Welding Co., Ltd. (Fig. 5).

Operation of the Pre-refining Furnace

At present the refining of a heat in the new Brymbo pre-refining furnace takes about 1–1½ hours. The working of a typical heat is as follows:

Analysis of Blast Furnace Metal:	C	4·15%
	Si	0·47%
	S	0·048%
	P	0·63%
	Mn	0·85%
Temperature of Blast Furnace Metal:	1,385° C.	
Analysis of Final Metal:	C	1·68%
	Si	Trace
	S	0·04%
	P	0·036%
	Mn	0·14%
Analysis of Final Slag:	CaO	43·2%
	SiO_2	14·8%
	P_2O_5	9·1%
	(Fe)	6·9%

Total Heat Time (charge to tap): 1–1½ hr.
Oxygen Used: 1,000 cu. ft./ton of metal
Percentage Scrap Melted: 6·55
Overall Efficiency of Oxygen Usage: 100% plus
Overall Yield of Metal: 93%
Rise in Temperature: 150° C.

It is hoped that in the course of the next few months these figures will be appreciably improved. For example, it is proposed to try to increase recovery still further by re-charging to the pre-refiner some of the final slag produced after the final decarburisation in the arc furnaces. This slag tends to be high in iron oxide content, but (because the phosphorus has been removed in the pre-refining step) is low in phosphorus.

One of the additional advantages of the use of the pre-refiner, which may not be evident at first sight, is its ability to absorb quantities of large-sized and awkwardly-shaped scrap. Large lumps of pit scrap cannot be satisfactorily melted in the arc furnace because they tend to cause electrode breakage; in the pre-refiner they are

consumed easily and cheaply. High silicon skull and scrap can be similarly melted.

After removal from the pre-refiner, the hot metal is transferred at once to one of the three new 40-ton electric arc furnaces in which the scrap has been brought to a state of incipient melting.

Operation of the Electric Arc Furnaces

The 40-ton arc furnaces in the new melting shop at Brymbo, which operate on a charge of approximately 45–50% hot metal, are able to turn out heats of finished steel at the rate of one every 4½ hours (tap-to-tap time) at present giving a productivity of about 10 tons/hr. It is expected that this also will be improved upon.

A typical electric furnace heat made under these conditions is as follows :—

2.50 p.m.	Last tap. Furnace fettled.
3.35 p.m.	25 tons of scrap charged. Power on at 325 volts, 20,000 amps. to melt down.
5.05 p.m.	20 tons pre-refined iron charged.
5.35 p.m.	Temperature 1,520° C.
5.50 p.m.	Oxygen blown intermittently for 25 mins. through ¾ in. pipe. Suitable additions of lime and limestone made to slag.
6.35 p.m.	Sample taken, 0·56% C.
6.55 p.m.	Manganese added.
7.20 p.m.	Tapped. (Silico-Manganese Steel, C. 0·55%, Mn 0·82%, Si 1·9%, S 0·034%, P 0·025%).

(Delay of 20 mins. due to faulty cooler pipes).

For steel made in this way, the electric power consumption works out at an average of 395 kWh./ton, and the oxygen consumption (in the electric furnace) at 460 cu.ft./ton. Counting the oxygen used in the pre-refining furnace, the total oxygen consumption per ingot ton is 900 cu. ft. For the same type of steel made in the old 30-ton electric furnaces, working on all-scrap charges, the usual heat time and power consumption are, in many instances, double these figures, and total oxygen consumption averages 500 cu. ft./ton.

Future Developments

There is no reason to think that the system of pre-refining now in operation at Brymbo must necessarily be confined to electric steel plants. Unlike his Continental competitor, the British open hearth steelmaker normally has to work with a pig iron containing anything up to 1% phosphorus, whereas in Germany, for example, open hearth furnaces operate with "stahleisen" pig iron which contains no more than 0·2% phosphorus.

The Brymbo pre-refined development has shown that there is no technical reason why British open hearth operators should not now enjoy the same advantages. The scale upon which pre-refining operations would need to be undertaken would have to be considerably expanded, but this should not present any insuperable difficulty.

Brymbo Steel Works Ltd., one of the smaller steel-making concerns, with no research laboratory of its own, has pioneered this technique quite independently, and in doing so has had the benefit of advice and assistance from the British Iron and Steel Research Association.

Nickel Supplies

ALTHOUGH nickel consumption in 1958 was considerably lower than production capacity, Dr. John F. Thompson, Chairman of the Board of The International Nickel Company of Canada, Ltd., told shareholders at the annual meeting in Toronto that "consumers of nickel must be assured of plentiful supplies in the years ahead if the full market potential of the metal is to be realised." Nickel production must be capable of meeting surges in demand that will arise during the anticipated upward trend in nickel consumption, he declared. Dr. Thompson said he could not emphasise too strongly the long-range importance to the company and to the nickel industry in general of International Nickel's new mining project at Thompson, Manitoba, and asserted that prompt completion of this project, which will increase the company's total annual nickel production capacity to 385,000,000 lb., beginning in 1961, will contribute greatly to the attainment of this goal. "But we set no ceiling on the demand that can be created for nickel, and we must do whatever is necessary to assure that future supplies will always be more than adequate," Dr. Thompson continued. "As a consequence we are actively continuing our exploration in Canada and throughout the world for still further sources of nickel."

Referring to the Manitoba project, the Board Chairman stated that "underground development and construction of surface and town facilities at Thompson, Manitoba, are proceeding on schedule. Favourable results in the exploration of the ore bodies revealed that the Thompson Mine would be capable of meeting the planned objective of the Manitoba project of 75,000,000 lb. of nickel annually. This made it advisable to postpone work at the nearby Moak Mine and concentrate on the rapid development at Thompson."

"In the 29 months since active development work has been under way, the company has expended in excess of $60,000,000 on this project and, in addition, it has advanced $20,000,000 to The Manitoba Hydro-Electric Board to assist in financing the development of power facilities in the area. Expenditures by the company for the Manitoba project for the balance of the year are estimated at over $30,000,000."

"It has now been decided," Dr. Thompson told shareholders, "to construct an electrolytic nickel refinery at Thompson with a capacity of up to 75,000,000 lb. of nickel per year, the initially scheduled capacity of the Manitoba project. In the original programme, decision on the process to be used was deferred until completion of experimental studies. These studies have led us to the decision that electro-refining would be the most suitable and economical procedure. In making arrangements for electric power, the company included refining in its estimated requirements from the Kelsey hydro-electric plant being built by The Manitoba Hydro-Electric Board on the Nelson River 53 miles from Thompson.

"The refining process to be employed was developed by research scientists and engineers of the company. Its suitability has been demonstrated by commercial operation since December, 1956, in a section of our nickel refinery at Port Colborne, Ontario. A main feature of the process is the direct electrolysis of nickel matte, which eliminates high-temperature oxidation and reduction operations."

New Laboratory Block Opened

Improved Facilities for B.N.F.M.R.A.

Sir Alexander Fleck, Chairman of Imperial Chemical Industries Ltd., unveiling a titanium plaque at the opening of the new laboratory block.

THE opening of the new laboratory block at the headquarters of The British Non-Ferrous Metals Research Association in London last month was marked by the unveiling by Sir Alexander Fleck, Chairman of Imperial Chemical Industries, Ltd., of a plaque engraved in titanium, symbolic of the increasing importance of the newer metals. Provision of the new block was included in plans for expansion laid in 1937, when two such blocks were envisaged. The first of these was completed in 1939, but as a result of war damage it was the only part of the premises left in operation by 1945. Adjacent factory buildings were acquired on long lease for conversion into laboratories, and in 1950 reconstruction of the bombed laboratory block was completed. Development of the premises in this way led to a rather haphazard arrangement, with the laboratories of some of the research teams rather widely scattered. This and the continued congestion in some sections made clear the need for further space, and led to the decision in 1957 to complete the building plans formulated twenty years earlier.

The block now completed adds another 12,500 sq. ft. of floor space to the laboratories, bringing the total to about 53,000 sq. ft. It contains new corrosion laboratories, a large new metal finishing shop, extensions to the physics laboratories and the foundry. In addition, there is a new Council room and offices for the senior staff more convenient to the main entrance. Alterations to existing buildings have enabled a new creep testing laboratory to be built to take over 100 units, the former mechanical testing laboratory to be converted into a fatigue laboratory, and more space to be allotted to apparatus for the determination of gases in metals. Completion of the new building and other rearrangements and improvements will allow for a future expansion of about 20% in most sections, and will provide for some free space where equipment needed, perhaps, for only a year or two for a particular research project can be erected.

Following the official opening of the new block, a series of Open Days was arranged to allow representatives of member firms to tour the laboratories and to see at first hand some of the work in hand, albeit only a small selection of the forty or so researches in progress.

Foundry Work

The first part of the new building to be completed was the extension to the foundry. Although there has been no radical change in the work of this section, researches requiring melting and casting facilities have increased considerably over the past five years, and the floor space became congested when the range of gas-fired crucible furnaces was extended and was supplemented by a bale-out furnace for die casting. Matters were made worse with the installation of a 600 lb. low-frequency induction furnace for experiments with refractories having the object of extending the use of this type of furnace to high melting point alloys, such as the cupro-nickels.

Now, a new bay has been built on to the foundry and all moulding, core-making and fettling have been transferred to this, leaving the original foundry for melting and casting only. In addition to the sand preparation plant, a small moulding machine has been installed in the new bay, so that the standard castings used for research into the sand casting qualities of metals can be moulded with better reproducibility. It also contains a shell moulding machine, apparatus for the CO_2 process, core ovens and storage space for patterns.

At one end of the new foundry are two small laboratories, one containing a high-frequency induction furnace for melts of up to 20 lb. of copper or nickel, enabling melts to be prepared under special atmospheres, and a vacuum melting furnace of similar capacity. The other laboratory is devoted to research work on argon or hydrogen atmosphere brazing and vacuum brazing of high temperature steels, nickel alloys and titanium.

The results of the research work displayed in the foundry show that even with traditional materials like gunmetals, research pays. The origin of the compositions

The new block on the right has been built in keeping with the wing built in 1938.

The new moulding bay contains plant for sand moulding, the CO_2 process and shell moulding.

used at present is lost in antiquity, and a systematic study has made it clear that they can be improved. For certain purposes, particularly where thick sections are involved, none of the gunmetals in common use is ideal, the best all-round combination of good mechanical properties together with ease of casting being obtained from an alloy outside the present ranges specified.

To help in formulating sensible standards for gunmetals, the B.N.F. is also making a detailed examination of the effect of the main impurities. Many foreign standards specify limits for a whole range of impurities, though there is little published evidence to suggest that they are harmful. Already the research has shown that sulphur, which is frequently limited in American and German standards, for example, has no adverse effects even when present in quite large amounts : the influence of arsenic, antimony, bismuth and iron is now being investigated.

Probably in the long run the most important of the researches on casting is an investigation into running, gating and feeding, much of it applying equally to light alloys and copper alloys. The majority of defective castings are the result of lack of attention to these points. For some years, the basic principles of the design of good running systems have been under investigation for various typical castings made in different metals, and now the effort is being transferred to assisting members in applying the results to production castings.

A new research has been started on the casting and properties of high-silicon aluminium-silicon alloys which have recently been attracting attention in the motor industry, and other work in progress is concerned with improving the resistance to stress corrosion of the high-strength cast aluminium alloys used in the aircraft industry. Some results of this suggest that LM10, the popular aluminium-magnesium alloy, can be improved considerably by small modifications to the composition.

High Temperature Brazing

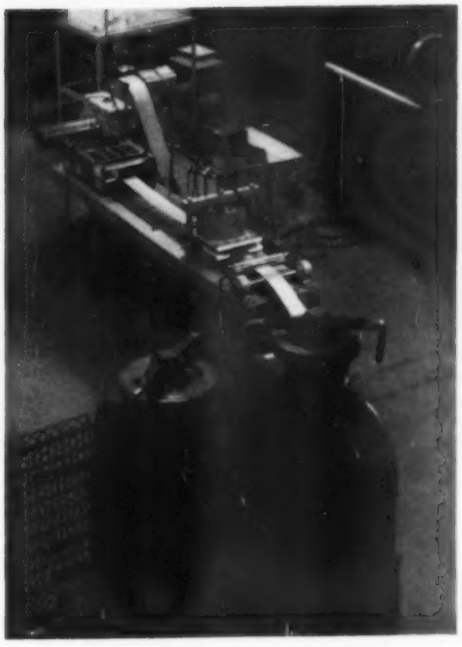
Reference has already been made to the brazing of high temperature alloys such as Nimonics, which are more difficult to braze than normal materials since they invariably have refractory oxide films which hinder the wetting of the surface by the brazing metal. Furthermore, the conditions in which they are used are more arduous than normal components have to withstand, so that soundness of the joint is of the utmost importance. The work covers fundamental aspects such as joint design and method of heating necessary to ensure complete soundness of joints, the correct combinations of brazing metal and basis metal for different circumstances, and the high temperature strength of the joints. High temperature brazing is now coming into industrial use and could do much to cheapen, for example, the production of gas turbine parts where at the moment much of the assembly has to be carried out by high precision machined joints. Work on brazing titanium alloys, where similar problems are encountered, has just started.

Metal Working and Treatment

Although the B.N.F. has not in the past undertaken work on the fundamental aspects of the working of metals, it has plant for rolling, extrusion and forging on a semi-industrial scale. This includes a 12 in. $\times$ 12 in. rolling mill fitted with load meters and used at present for determining rolling loads for different copper alloys, a 500-ton vertical press for extrusion or forging, a large forging hammer, and ancillary preheating and annealing furnaces. The equipment makes the laboratories self-contained as regards production of experimental material in a form suitable for testing.

There is sufficient space in the metal working shop for fairly large pieces of equipment to be erected. At present it houses the prototype of a novel machine developed by the B.N.F. for correcting strip for various rolling faults. This machine is designed to be placed between the working rolls of the mill and the coiler. It helps to correct such faults as "waviness" and

In the new electroplating laboratory developments can be carried right through to semi-industrial scale trials.



Strip being treated in a prototype roller-stretcher machine for correcting edge curvature and other rolling faults.

"spoutiness" and, in addition, equalises the internal stresses in the strip. If there are uneven stresses, strip slit into narrow widths for presswork tends to take on a longitudinal curvature which causes jamming in modern press tools where the strip has to pass through a number of successive operations. Although residual rolling stresses are not the only cause of this longitudinal curvature, the B.N.F.'s device, for which patent protection has been sought, should help a great deal to meet the exacting demands of the presswork industry. The development of this machine has been one outcome of a research concerned with rolling copper alloys, in which rolling loads for different alloys have been compared and the factors affecting the shape of strip during rolling have been evaluated.

How much hydrogen is permissible in the atmosphere when bright annealing high-conductivity copper and the reasons why adjacent turns sometimes stick together when bright annealing coils of wire or strip are being investigated in the General Metallurgy Section, which has recently been extended. Although bright annealing has been in commercial use for many years, there is surprisingly little information about the permissible hydrogen contents of annealing atmospheres to avoid embrittlement of high-conductivity copper at different temperatures. Similarly, the factors on which the tendency to sticking depend have never been looked into, although this is obviously a form of pressure welding.

Metal Finishing

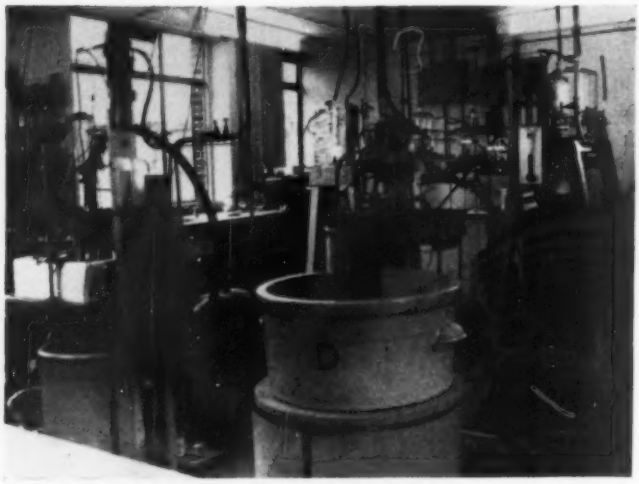
A new laboratory in the basement of the new block houses the electroplating work which formerly went on in several scattered laboratories. It is equipped for work ranging from bench-scale experiments on the fundamental process to plating on a semi-industrial scale. The laboratory has equipment for measuring cathode potentials, throwing power, the build-up of stresses during the deposition of metals, and the ductility and adhesion of coatings.

The assessment of the corrosion resistance of electroplated coatings of nickel/chromium is an important feature of the work, and good use is made of the roof of the laboratories for outdoor exposure trials. Accelerated tests, such as the sulphur dioxide test, in the development of which the B.N.F. has played a prominent part, can readily be compared with the results of actual outdoor exposure in severe industrial conditions without looking further for a test site.

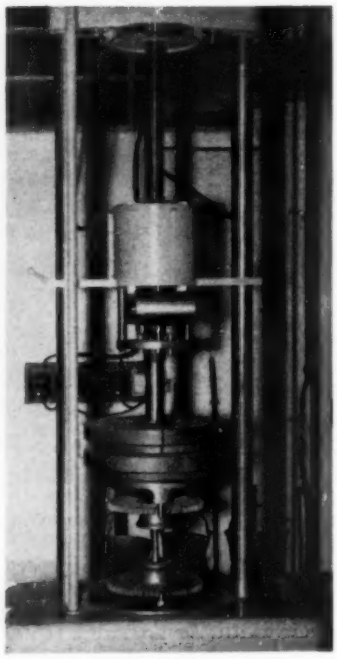
Displayed in the laboratory were the main results of the B.N.F.'s work on the durability of nickel/chromium plating, showing that durability does not depend on the type of nickel used, that modern plating baths can be operated for long periods without the durability of the nickel deteriorating, but that the life of plating out-of-doors is strongly dependent on the thickness of nickel applied. Here the B.N.F. coatings gauge looks as though it is going to be of great help in maintaining the reputation of the plating industry. It provides a completely non-destructive method of measuring nickel thicknesses on steel, brass or zinc alloy die-castings just by applying a probe to the surface. The immediate aim is to speed up readings, improve reproducibility and simplify calibration: it should not be long before the plater has an instrument suitable for routine inspection.

Much has been talked recently about the value of crack-free chromium for corrosion resistance. Research on the subject has been going on at the B.N.F. for several years. Because ordinary chromium plating develops cracks if it is much more than 0·00002 in. thick, the inherently good corrosion resistance of chromium is lost. Means have to be found for making thicker deposits without cracks. Studies of the effect of altering solution concentration and plating conditions have suggested modifications allowing modest increases in thickness of chromium, and the extra durability to be obtained from these coatings is being determined at the present time. For much of the work, plated zinc alloy die cast motor car trim is being used.

Geiger counters and radioactivity are not usually



This laboratory is set aside for sea-water corrosion studies, chief of which concerns heat exchanger tubes.



Ten ton direct stressing Vibraphore fatigue machine.

associated with electroplating. However, compounds labelled with radioactive tracers are proving most useful in fundamental work designed ultimately to improve nickel plating solutions. It is known that the complex organic substances added to modern nickel plating solutions to give the deposit such qualities as smoothness and brightness while retaining reasonable ductility become incorporated in the nickel to some extent, though the amounts involved are too small for ordinary chemical analysis. With typical addition agents specially prepared by the Radio Chemical Centre with a radioactive isotope such as carbon C_{14} or sulphur S_{35} as tracer, the extent of incorporation of the organic agents can be determined by checking the deposits with a Geiger counter. So far as is known, this application of radioactive tracers to electroplating problems is unique.

Corrosion

The greater part of the Corrosion Section is now housed on the top floor of the new block. Much of the work relates to the use of non-ferrous metals in supply waters and, although part must be carried out at field stations, a great deal can be done in the laboratories to study the effect of variations in water composition, making use of synthesised waters. Some of the more basic work, such as research into the factors controlling pitting corrosion, involves electrochemical measurements over long periods, and novel recording methods have been devised.

For studying the behaviour of galvanised hot water tanks, a whole laboratory is taken up with a battery of twenty small hot water tanks and boilers, different groups of tanks operating with different water compositions. In the meantime, field tests at some fifty sites have shown the value of magnesium anodes for preventing early failure of tanks where the water is unduly aggressive. The evaluation of aluminium alloys for conveying water supplies has shown promising results for clad tubes, and arrangements have been made to test these materials in plumbing installations. Elsewhere, reference is made to the use of sprayed coatings of other alloys as a means of protecting high-strength aluminium alloys in corrosive environments.

Two researches are in progress in connection with the use of copper alloys in supply waters ; one, an investigation of the dezincification of hot pressed brass fittings which has been a trouble in a few areas in the country ; the other, a research into the pitting corrosion of copper water pipes. The fact that this pitting is usually caused by films formed in the bores of tubes during manufacture was established some time ago and prominence has been given to helping manufacturers avoid them.

Sea-water corrosion studies are also important. The current work arises from the problems encountered with copper alloy heat exchanger tubes handling polluted estuarine water at power stations and oil refineries, and in ships, and a new range of alloys is under development for service in this field. In the sea-water corrosion laboratory there are several jet test sets which still remain the most valuable tool in this work. Cathodic protection and wastage of ships' propellers are among other subjects being studied in this laboratory.

Greater use of metal for decorative panelling in buildings has led to the commencement of a new research to find a means of preserving the natural appearance of copper and its alloys. New methods of surface treatment in conjunction with modern synthetic lacquers are being examined.

Lead-Clad Steel and Lead Cable Sheathing

Lead has outstanding resistance to corrosion, particularly towards sulphuric acid and sulphur-containing fumes. However, it must be well supported as it tends to creep even under its own weight. A new B.N.F. product, lead-clad steel, combines the corrosion resistance of lead with the structural stability of steel and should lead to increasing use of lead in the chemical plant industry, where at present it is often applied by the costly process of hand burning. The B.N.F. has developed a method of

rolling lead on to sheets of steel and industrial trials have proved that it is possible to make lead claddings up to ¼ in. thick on large steel plates which can be welded together without difficulty. Several small articles made in this way were shown in the laboratory, and it is hoped to get this interesting new process into commercial production.

Despite competition from other materials, lead is still the most important cable-sheathing material. The chief requirements are good resistance to fatigue cracking for sites where there is vibration, ductility, and ease of extrusion. The B.N.F. has recently patented a range of dilute lead-antimony based alloys which look as though they will fulfil these requirements better than any of the alloys in current use. Laboratory tests of experimental commercially extruded sheaths in these alloys have been in progress for two years, and arrangements for field trials have just been made. The possibility that the same basic composition in varying degrees of dilution could fulfil practically all requirements offers a great advantage when cable presses are being changed from one type of production to another.

Structural Uses of Aluminium Alloys

To help the designer make the best use of aluminium alloys for land transport applications, such as railway coaches and buses, the B.N.F. is making a detailed comparison of the fatigue properties of medium strength light alloys and structural steels normally used in the transport industry. Tests are going on, not only with plain specimens but also with specimens having notches, the results of which will influence joint design.

Two Vibraphore direct stressing fatigue machines, one of 10 tons capacity and the other of 2 tons capacity, are in use for this work in a new fatigue laboratory which contains several other varieties of fatigue machines for tests under bending stresses. Some of these have been adapted for a rapid fatigue test on which the B.N.F. has been doing a considerable amount of development work. Fretting fatigue in connection with aluminium alloys is also being investigated, the question being of great importance in the aircraft industry, and various anti-fretting agents are being compared.

A great deal of attention has been given to improving the transverse ductility of large high-strength aluminium alloy extrusions and forgings now used in aircraft. The research has mainly concerned D.T.D. 683, the aluminium-copper-zinc-magnesium alloy which has a high proof stress. The low ductility sometimes encountered across the direction of working has meant that unusual care has had to be exercised in using large extrusions and forgings. An explanation for this low transverse ductility has been provided by research work, and recommendations for improving the position, among other things by modified forging techniques, are being tried out at the present time.

In the Corrosion Section of the laboratories there are some interesting examples of the use of sprayed coatings of other aluminium alloys as a means of protecting high-strength aluminium alloys in corrosive environments. Promising results have been obtained in exposure tests at different sites lasting for up to four years. This work should be of particular value in applications of these alloys to structures such as bridges and crane jibs.

The Newer Metals

Much of the B.N.F.'s work on the newer metals is now connected with the nuclear power industry, though research on titanium during the last ten years has provided a good deal of basic information on the types of alloys from which creep resistance coupled with good forgeability can be expected. One laboratory is set aside for an investigation into the metallurgy of thorium and its alloys, the object being to produce thorium-based materials having adequate strength at high temperatures to be used as nuclear power fuel elements. In its unalloyed form, thorium is insufficiently strong at the operating temperatures of a reactor, but some promising high-strength materials have been developed and their creep properties are being evaluated. Special creep testing equipment has had to be developed to enable the testing to be carried out in purified argon, since thorium is too reactive to test at high temperatures in air.

Equipment for conducting creep tests on reactive metals in an atmosphere free from oxygen.

Another research is concerned with the development of high-strength zirconium alloys, which are of interest as canning materials for nuclear fuel elements, and the same type of creep testing equipment is being used. Work is also commencing on certain aspects of the metallurgy of the production of uranium fuel elements.

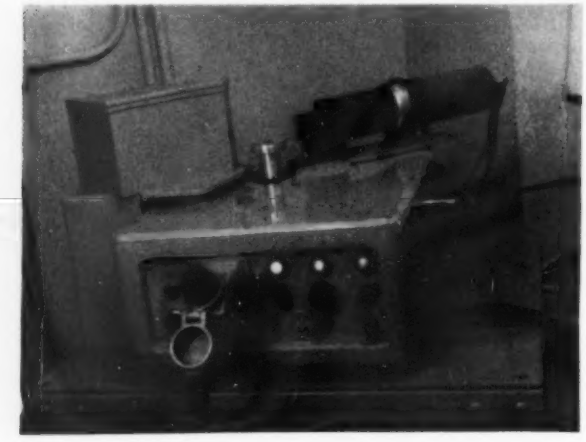
X-Ray Fluorescence Analysis

More space has had to be allotted to the Physics Section, which has recently embarked on two new activities—X-ray fluorescence analysis and instrumentation. Determination of the zinc content of brass in one minute with an accuracy at least as good as routine chemical analysis was demonstrated on an X-ray spectrometer in the physics laboratory. Research on the metallurgical

The recently acquired flame spectrophotometer.

uses of X-ray fluorescence analysis has been going on at the B.N.F. for the past two years, using a spectrometer made in the workshop. The method is akin to spectrographic analysis, but instead of sparking the metal and examining the light spectrum produced, the metal is irradiated with a beam of X-rays and the X-ray fluorescence is split into a spectrum and analysed by means of a scintillation counter.

So far, the B.N.F.'s work has been confined to analysing brasses, tin bronzes and cupro-nickels, in all of which the main elements can be determined accurately, but it is soon to be extended to other metals and to ores. The prototype of a commercial instrument, loaned to the B.N.F. for evaluation, designed to carry out automatically complete analyses of alloys and record the results on a paper tape, was also shown.



An X-ray spectrometer built in the workshop for research on X-ray fluorescence analysis.

Instrumentation

In the physics laboratory there was a working model of an eddy-current instrument sorting brass tubes with manufacturing faults from good tubes. Automatic inspection of this kind is becoming more and more necessary with larger scale production and automation in the non-ferrous metals industry. Research is going on into several aspects of instrumentation. The one concerned with eddy-current testing is providing information about design of search coils for specific inspection problems, thus helping members of the Association to make the best use of available commercial instruments. The development of a satisfactory radiation pyrometer for measuring the temperature of aluminium alloys during hot working is the objective of another research. The low and variable emissivity of aluminium makes radiation pyrometry particularly difficult.

Researches of this kind are forming a background for an advisory service on instrumentation problems which the Association provides for members. A close watch is kept on new instruments coming on the market and many of these have been obtained on loan for evaluation.

Acid Erosion of Teeth

THE Industrial Injuries Advisory Council has been asked by the Minister of Pensions and National Insurance to consider whether erosion of the teeth due to acid should be a " prescribed disease " under the National Insurance (Industrial Injuries) Acts and, if so, for what occupations. The effect of prescribing a disease is that if it is developed as a result of work in whatever occupations may be specified in the regulations, benefit under the Industrial Injuries Act may be paid for the resulting incapacity or disablement.

It has been suggested that the acid given off in some industrial processes, whether in the form of fumes or dust, may damage the teeth of persons working in the immediate vicinity. The Council will be investigating whether, if this is found to occur, the resulting erosion of the teeth satisfies the conditions laid down in the Act for prescription. Any person or organisation having information or views on the question should submit them in writing to the Secretary, Industrial Injuries Advisory Council, 10 John Adam Street, London, W.C.2. by September 15th, 1959. An explanatory memorandum will be sent on request to anyone wishing to give evidence.

British Exhibition in New York

SIR NORMAN KIPPING, Director General, Federation of British Industries, and Mr. W. P. N. Edwards, a Director of F.B.I., recently visited the U.S. to make preliminary arrangements for the British Exhibition which will open in the Coliseum Building, New York, on 10th June, 1960. Britain plans to put on the most striking demonstration of advances in British science, technology and engineering ever to have been staged in the New World. This will be combined with an imaginative display of Britain's most famous top quality consumer goods. The exhibition, which will last for two weeks, is expected to be the largest ever staged by one country within the confines of another.

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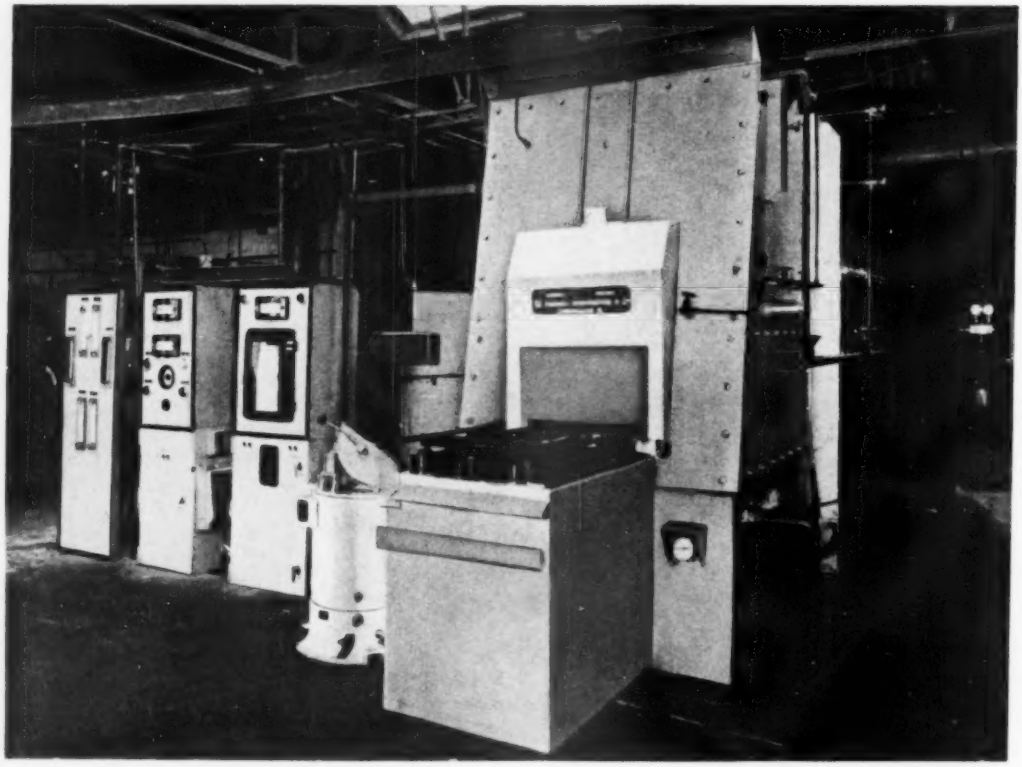

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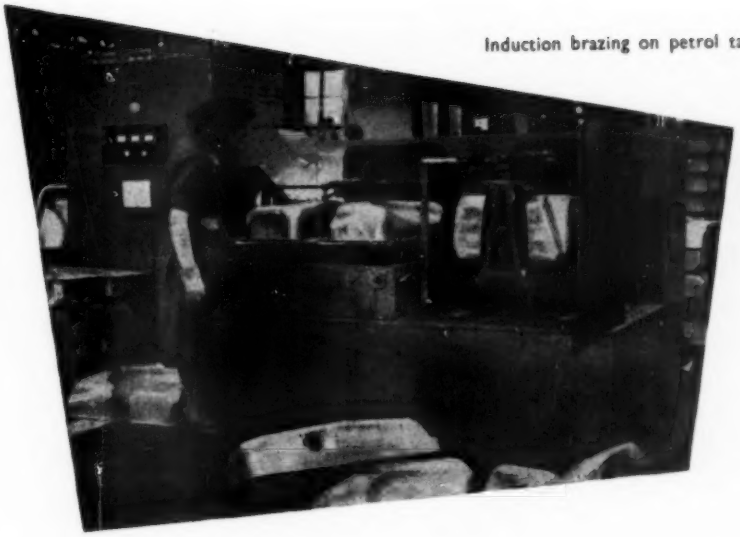

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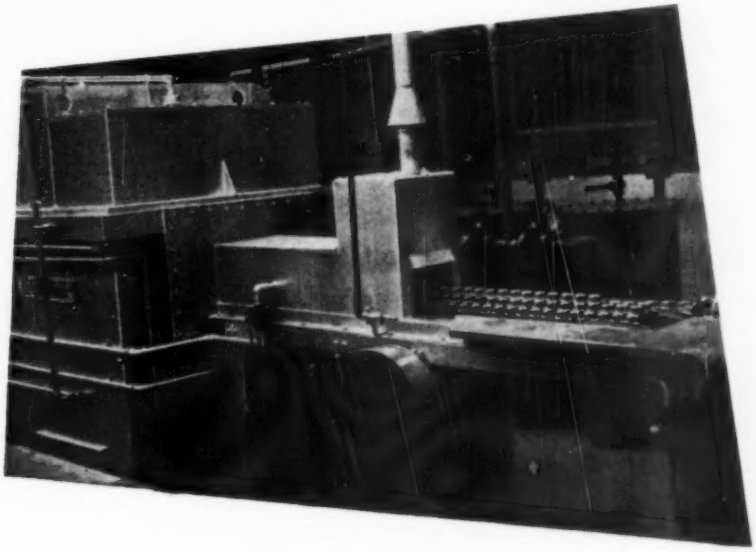

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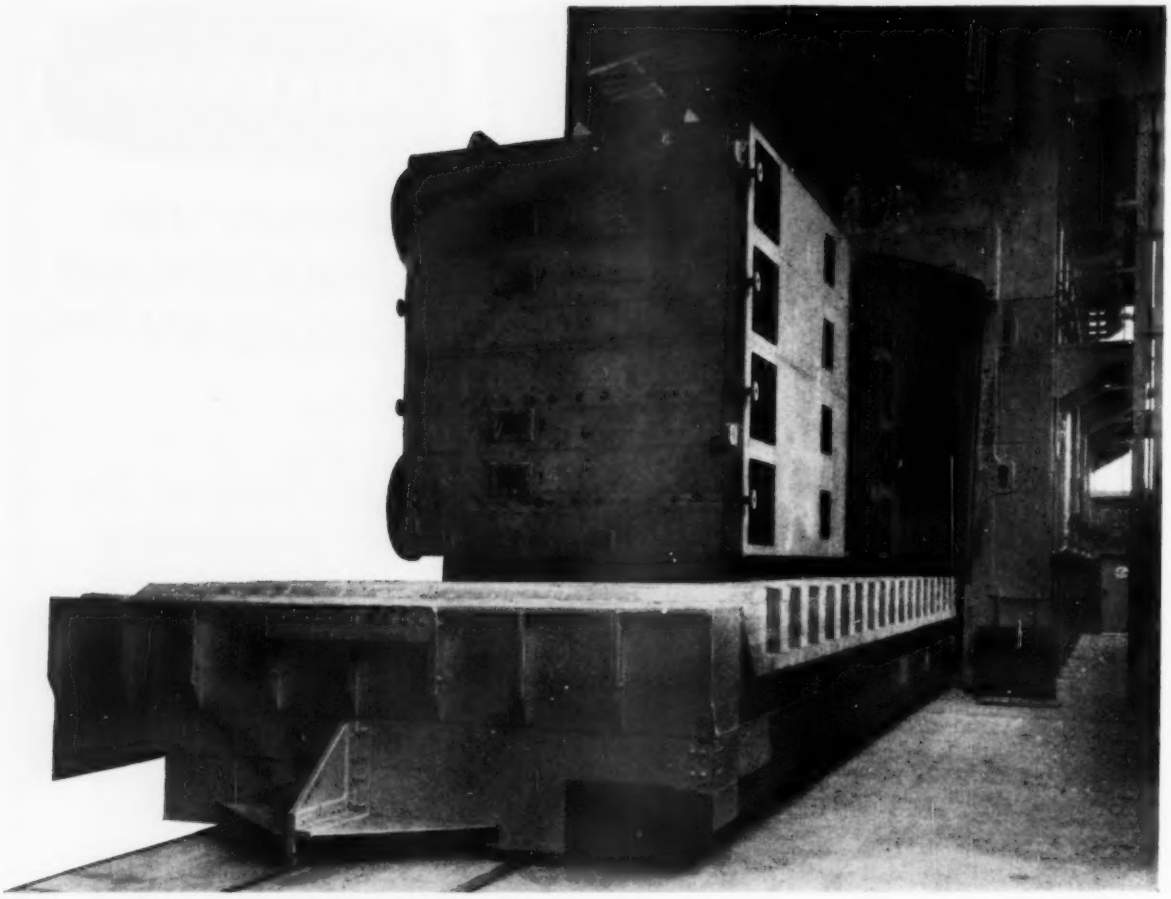

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INCANDESCENT have wide experience in building bogie hearth furnaces for many processes—stress relieving, annealing, heat treatment of forgings, mill rolls, etc. The furnace illustrated is installed at the works of Whessoe Ltd., Darlington, manufacturers of pressure vessels and chemical plant.

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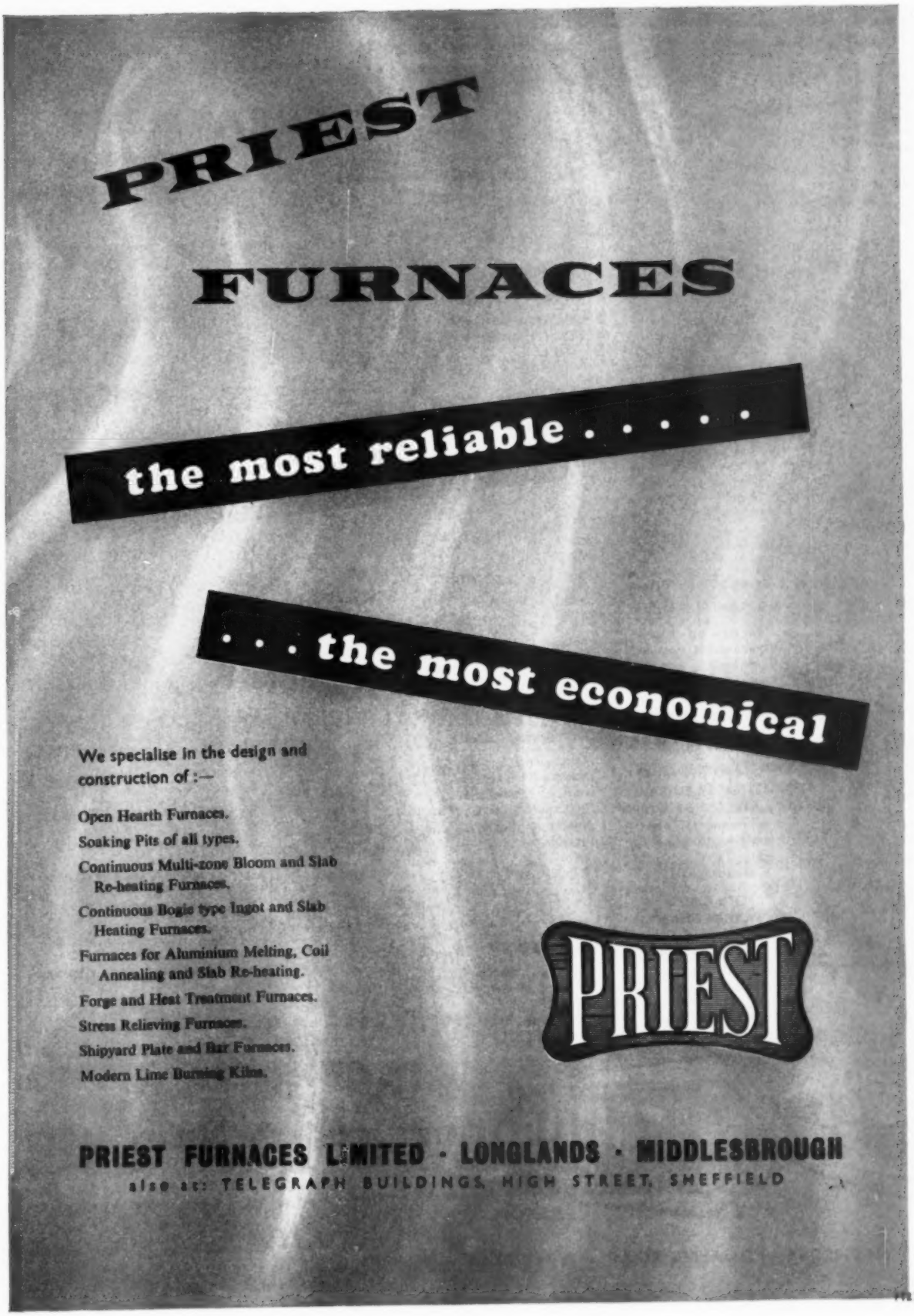
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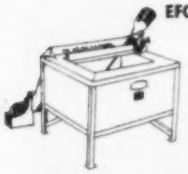

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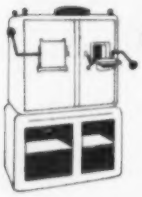

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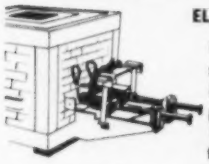

Hardening high speed steels, aluminium brazing and all processes up to 1300°C. with bath free from metallic oxides.
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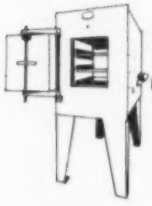

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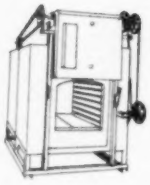
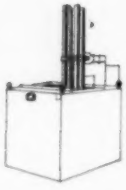


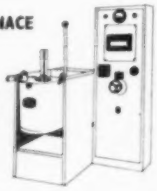
Box carburising and general treatment to 1150°C.
Publication R.3.

EFCO ELECTRIC SALT BATHS



Cyanide hardening, carburising, neutral treatment to 1000°C.
Publication R.1.

EFCO SALT BATH FURNACE MIDGET TYPE



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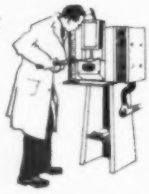

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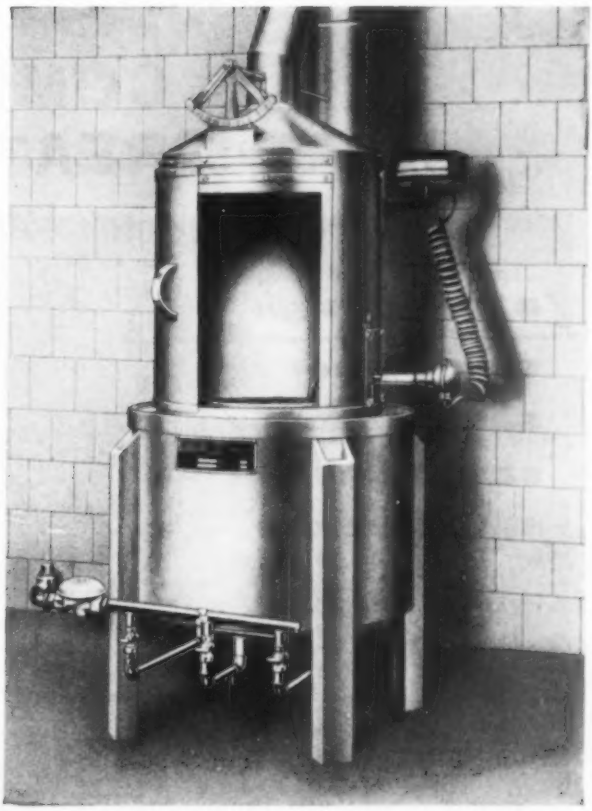

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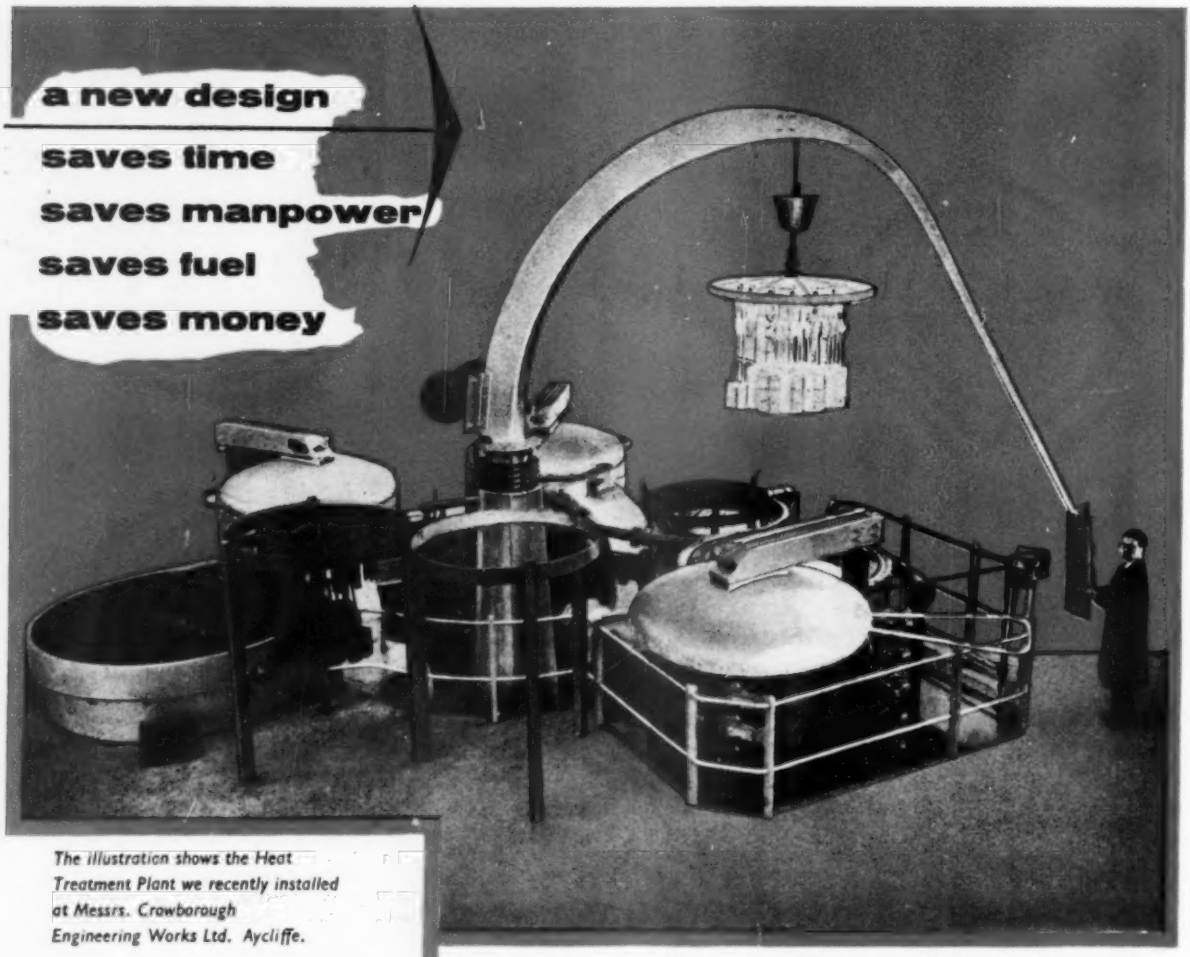

The illustration shows the Heat Treatment Plant we recently installed at Messrs. Crowborough Engineering Works Ltd. Aycliffe.

The complete unit installation at Aycliffe consists of Hardening Furnace, two Tempering Furnaces, Water Quench Tank, Oil Quench Tank, Loading and Unloading Racks. The unit is serviced by a fully-automatic, centrally-located, electrically-operated crane. The two re-circulating Tempering Furnaces utilise the waste heat from the Hardening Furnace. Supplementary gas is automatically provided when necessary.

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Recent Heat Treatment Furnace Installations

Annual Survey of Developments

The exacting demands of industry are a constant challenge to the furnace designer and manufacturer, and the development of equipment to carry out heating processes with greater precision and control has been continuous. Although few recent installations depart from conventional practice, several designs have considerable technical interest, to which reference is made in this survey.

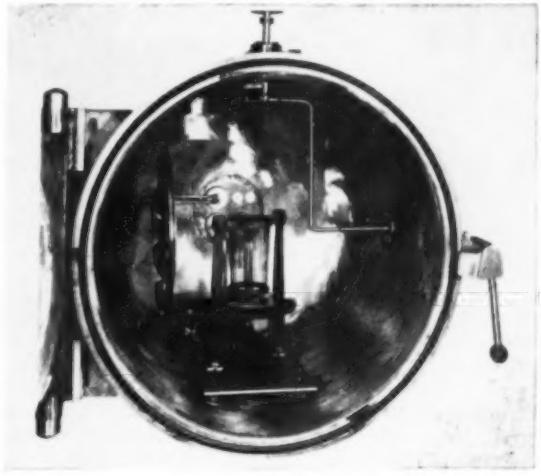
THE demands of various branches of engineering have necessitated improvements in technique in many metallurgical operations, and included among these have been developments and improvements in the industrial heat treatment of metals and alloys. Such improvements have contributed to the advance made in the quality of steel and in the development of many non-ferrous alloys. The necessity of controlling grain size, and the surface condition of the materials which have been heat treated, as well as their properties, has given rise to some interesting problems in heat treatment.

Improvement in heat treating methods and techniques involves such variables as furnace temperature, furnace atmosphere, heating time, cooling rate and quenching method. Such changes have not only been carried out by developments in solid fuel, oil, gas, or electrically heated furnaces; by an extended use of salt baths for heating; by the use of better and more rigidly controlled pyrometers of all types; by the development and application of controlled atmospheres; and by the use of proper quenching media and equipment; but also by a better understanding of the principles of heat treatment as applied to various metals and alloys.

Although the term "heat treatment" is often associated particularly with hardening and tempering, the results of many investigations have shown the importance of control on the quality of production in many other heating operations. In addition to equipment for hardening and tempering, therefore, plant for the wider application of heat treatment will be presented in this review, including some recent developments in induction heating equipment.

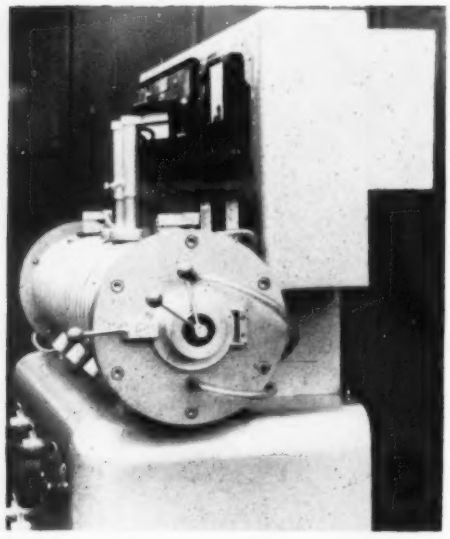
Vacuum Treatment

Continual efforts are being made by manufacturers to develop equipment for carrying out heating processes with ever greater precision and control, at the same time maintaining the highest reliability, even though the temperatures needed may be appreciably in excess of those sought only a few years ago. In addition to problems associated with high temperatures, oxidation and other contamination problems may arise, and it is not surprising that vacuum furnaces have become established, not only for melting but also for sintering, brazing and outgassing. Several firms have a number of types of vacuum furnace in production embodying interesting features, and considerable attention is being given to the further development of this relatively new furnace technique. Not only are vacuum furnaces being used industrially for special high quality products, but general-purpose vacuum furnaces, suitable for research work or small-scale pilot production, are now being made. Such furnaces enable laboratories and small workshops to cover, with a single unit, a wide range of vacuum heating processes. The furnace illustrated in Fig. 1, which is made under the agreement recently concluded between The General Electric Co., Ltd., and Vacuum Industrial Applications, Ltd., provides facilities for carrying out *in vacuo* the following operations: melting, casting, heat treatment, sintering and outgassing, using induction or resistance heating. The work chamber has an internal diameter of 24 in. and is clad with stainless steel to reduce degassing to a minimum. For resistance heating, graphite, tantalum, tungsten or molybdenum is used for the heaters, according to the particular process and specified vacuum. Using a graphite crucible it is possible to obtain temperatures as high as 1,800° C. A 10 kW., 10,000 c./s. generator is supplied for induction heating, and temperatures in excess of 2,400° C. can be achieved in sintering, when the power is absorbed in a graphite susceptor. A two-stage high-speed pumping system, comprising an oil vapour pump and a Kinney rotary



Courtesy of The General Electric Co., Ltd.

Fig. 1.—A resistance heating vacuum furnace for general heat treatment processes.

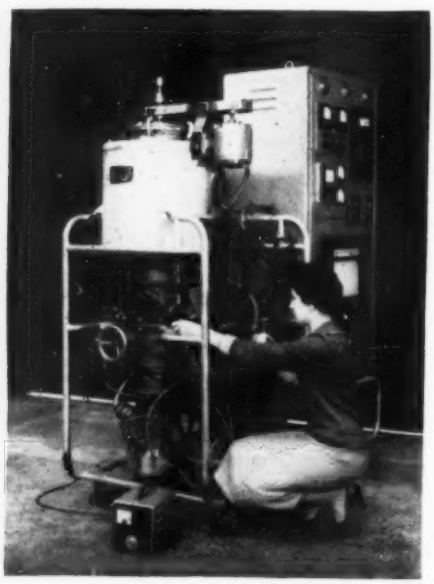


Courtesy of Vacuum Metallurgical Developments, Ltd.

Fig. 2.—High-vacuum high-temperature tube furnace.

pump in series, enables a vacuum of 10^{-5} mm. Hg to be attained.

The first of a line of furnaces by Vacuum Metallurgical Developments, Ltd., which permits water quenching from high vacuum at temperatures up to 1,250° C. within a few seconds, is practically completed. The material to be processed—steel or Nimonic alloys—is contained in a heat-resistant basket in a vertical molybdenum resistance furnace. On reaching full temperature, argon is admitted to the furnace chamber, a bottom door opens automatically, and the work basket drops through a sealed argon hood into the quench. The work is in contact with argon for only a few seconds, and high-purity gas is not normally required.



Courtesy of A. R. Wade, Ltd.

Fig. 3.—Vacuum heat treatment furnace used for research on titanium and similar metals.

The high temperature tube furnace shown in Fig. 2 comprises a refractory tube of about 2 in. diameter with a molybdenum winding embodied in refractory and surrounded by concentric radiation shields of molybdenum and Nimonic alloy. The refractory tube is continuously supported to prevent sagging at high temperatures, and both ends are supported in water-cooled holders. Temperature measurement is by platinum-rhodium and tungsten-molybdenum thermocouples. The furnace tube is sealed from the vacuum chamber, which can be separately pumped, and different gases may be admitted to each part. It is thus possible to operate the furnace with an oxidising atmosphere, and at atmospheric pressure, without damaging the windings.

The vacuum furnace shown in Fig. 3 is designed to achieve a vacuum of the order of 10^{-7} mm. Hg, and its maximum temperature is in the region of 1,200° C. It is a dual purpose unit, inasmuch as the plain door can be replaced by one incorporating a fan. In this form the furnace is evacuated down to a pressure of a micron or so, and pure gas is then introduced. The equipment then functions in the lower temperature ranges as an "air" circulation furnace. Temperature control is effected by means of a saturable reactor, and a three point recorder is incorporated. The equipment is at present being used in research on the heat treatment of titanium alloys.

Conventional Heat Treatment Furnaces

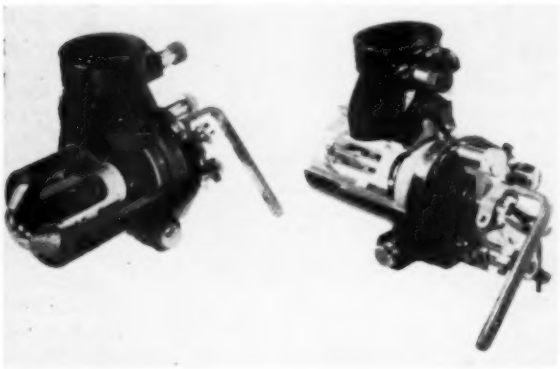
Furnaces for the heat treatment of engineering components cover a wide field of processes and designs, and many interesting installations have been commissioned recently, while contracts of considerable magnitude are in progress for both export and home applications. Notable among the former is the contract awarded The Incandescent Heat Co., Ltd., for a large coil-annealing installation at the new steelworks of the Sociedad Mixta Siderurgia Argentina (SOMISA). The order is for twenty-five single stack coil annealing furnaces with seventy-two bases, thirty-two forced cooling hoods, and three exothermic gas atmosphere plants, each rated at 10,000 cu. ft./hr. These furnaces are built to the design of the Lee Wilson Engineering Co., Inc., of Cleveland, U.S.A., for whom Incandescent are manufacturing licensees. The plant will handle coils up to 60 in. diameter in stacks up to 168 in. high, and will anneal annually 300,000 tons of cold reduced sheet and tinplate.

The majority of heat treatment furnaces commissioned or being built, whether for works at home or abroad, are developments of already familiar basic types. An example of this is the range of mesh belt conveyor furnaces for bright annealing, normalising or brazing, which now includes a new "hump-backed" type of special importance where pure hydrogen atmospheres are used. This Birlec design—which is available in a range of sizes from 6 in. belt width upwards—has inlet and outlet tunnels sloping downwards from the heating chamber, so that the gas atmosphere is retained in the latter with minimum end losses.

Many further examples could be given here, but reference will be made to others later in this review. For the precise heat treatment of particular products on a mass basis, continuous furnaces usually meet the need for speed and relatively low cost, but general-purpose

furnaces continue to satisfy a big need, while semi-continuous furnaces occupy an intermediate position. To give typical examples of new installations it will be convenient to refer to them in connection with the purpose for which they have been installed, exception being made with induction heating and salt bath furnaces, which are discussed under separate headings.

A new low-air-pressure oil burner, the Rotavac Model PRN, has been developed expressly for those furnace applications requiring highly efficient combustion with complete atmosphere control, while allowing accurate operation and ease of maintenance by ordinary personnel. The special features of this burner, which is shown in Fig. 4, include a single lever which controls both oil and air, keeping the ratio constant from maximum to minimum firing rate; any atmosphere in the furnace selected at will and maintained throughout firing range with uniformly high CO_2; variable air oil valve coupling allows selection of the correct ratio while the burner is running, and, when selected, the ratio remains constant from high to low flame; the flame shape can be adjusted while the burner is in operation; and reduced air pressure to give a smaller stable low flame for special applications is provided for by a flame shield. This



Courtesy of Nu-way Heating Plants, Ltd.

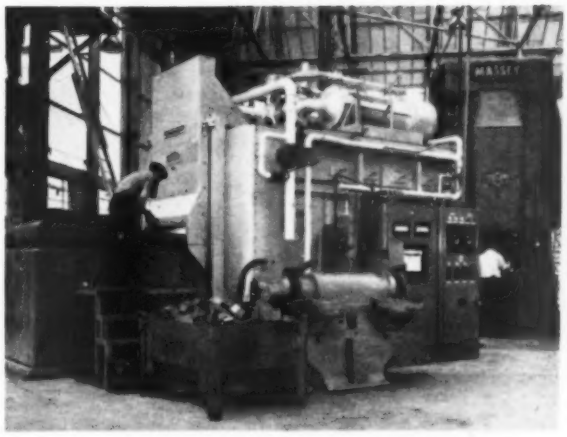
Fig 4.—A new low air pressure oil burner designed expressly for furnace applications requiring efficient combustion with complete atmosphere control.

burner is robustly constructed to burn any grade of liquid fuel with constant high efficiency.

Reheating

In integrated steel plants the soaking of ingots is carried out in furnaces heated by coke-oven or blast-furnace gas, or by a combination of the two, the only fuel used being the coal from which the blast-furnace coke is initially produced. In certain countries, however, electric energy is considered more economical for heating soaking pits, and in view of the high cost in this country of other heating media, a number of steel works have installed electrically heated soaking pits, as was mentioned in our last review. Whether the heating medium be solid fuel, oil, gas, or electricity, however, the primary objective of any heat treatment furnace is to give a satisfactory product at low cost, consistent with uniformity of heating.

The importance of uniformity in heating is particularly associated with extrusion, rolling, forging and presswork.

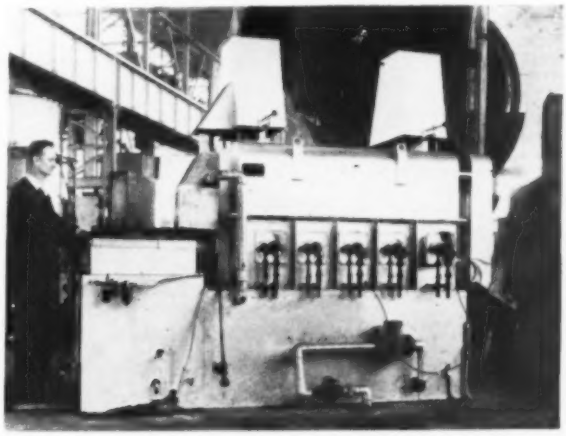


Courtesy of The Incandescent Heat Co., Ltd.

Fig. 5.—One of four Equiverse-fired continuous multi-cam pusher furnaces installed at Forgings and Presswork, Ltd.

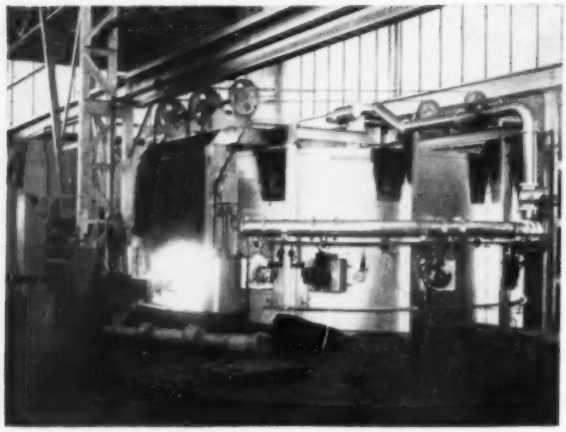
Four furnaces have recently been installed at Forgings and Presswork, Ltd., for heating billets to forging temperature at a rate of 1 ton/hr.; fuel consumption (town's gas) is 2 million B.Th.U./ton. One of these Equiverse-fired continuous multi-cam pusher furnaces is shown in Fig. 5. Round and square billets are pushed along six grooves in the furnace hearth, and are discharged singly at regular intervals ready for the press operator. In order to maintain constant tonnage with different sizes of billets, the cam speed can be varied to discharge from 100 to 600 billets an hour.

It is noteworthy that the Incandescent Heat Co., Ltd., have received an order for an annular hearth rotary furnace to be installed in Northern Italy. The furnace, which will be fired by the Equiverse system, using natural gas, will have a mean diameter of 6 m. and will be used for heating alloy steel blanks for piercing in a vertical press, the first operation in the production of high pressure liquefied petroleum gas bottles. High speed fully automatic manipulators, capable of handling up to 42 blanks an hour, are to be supplied with the plant.



Courtesy of Brayshaw Furnaces, Ltd.

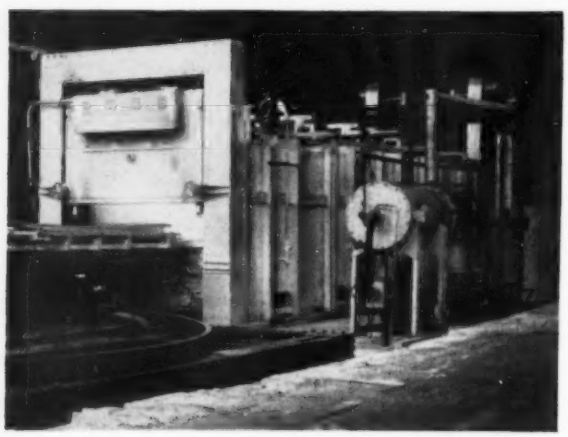
Fig. 6.—A gas and air-blast heated controlled atmosphere pusher type furnace for heating alloy steel blanks for forging.



Courtesy of The Incandescent Heat Co., Ltd.

Fig. 7.—Rotary hearth furnace for reheating billets for forging.

Heating alloy steel forging blanks in a specially prepared atmosphere on a continuous basis is carried out in the furnace shown in Fig. 6. This furnace is designed as a self-contained unit, complete with exothermic atmosphere generator mounted below the furnace, which has an output of 150 lb./hr. of blanks at a temperature of 1,180° C. The parts for treatment are pushed through the furnace in thin-walled heat-resisting steel tubes located in a heat-resisting steel muffle extending in the form of a sloping chute emerging at the rear of the furnace. The furnace illustrated is fitted with a twin pusher system operating in alternating sequence, and similar furnaces are in operation utilising four pushers, giving four runs of work with a maximum output of 250 lb./hr. These furnaces are arranged to accomodate heat-resisting steel tubes of $2\frac{1}{4}$, 3, or $3\frac{1}{4}$ in. diameter, and adjustments are provided for easy replacement of the tubes to suit the work being treated. The furnace is heated by a series of gas and air-blast burners firing alternately from each side of the furnace into refractory lined passages below the muffle, and exhausting through damper-controlled flues at each end.



Courtesy of Metalectric Furnaces, Ltd.

Fig. 8.—A large box type grooved hearth furnace designed for stress relieving seamless steel tubes.

At the new light forge of Walter Somers, Ltd., an interesting rotary hearth furnace is used for heating the billets to forging temperature. An unusual feature of this unit, shown in Fig. 7, is that the 16 ft. hearth is a truly rotary table, as distinct from the usual annular hearth moving round a central pillar. The arrangement allows full use to be made of the whole hearth area and longer billets can be heated than in an annular hearth of the same diameter. Eleven oil fired burners, arranged to fire tangentially, give a heating rate of 2 tons/hr. with a maximum load of 10 tons. The movements of the hearth and of the single hydraulically operated door may be controlled from either the main press control desk, or the forging manipulator.

Stress Relieving Furnaces

Fig. 8 shows a large box type grooved hearth furnace designed for stress relieving seamless steel tubes and for accepting net charge weights of 4 tons : the tubes are loaded into and from the furnace by a four-arm charging machine. This furnace is rated at 702 kW., has usable dimensions of 6 ft. wide, 2 ft. 3 in. to spring of door arch, heated length 38 ft., and is suitable for use with a controlled atmosphere and for temperatures up to a maximum of 1,000° C. Special features, provided to enhance temperature uniformity and the required heat treatment cycles, include the arrangement of elements in five separate sections or zones, each independently and automatically controlled by high/low rating instrumentation of Honeywell-Controls manufacture, atmosphere-circulating fans, and built-in cooling ducts connected to two cooling-air fans.

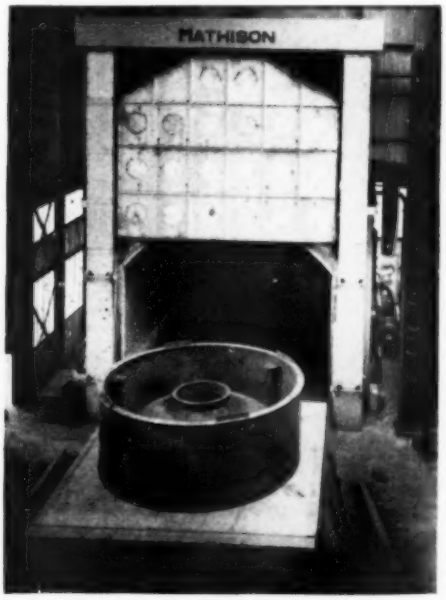
The stress relieving of large welded steel fabrications calls for careful heat treatment, particularly with large nuclear power vessels involving heavy plate welding. For this purpose, the furnace shown in Fig. 9 has been installed in the construction shop of Messrs. Head Wrightson Teesdale, Ltd. This furnace, which is of the vertical flame, high speed, recirculating type, is designed to cover the full range of treatments of steel vessels from 200° C. up to 900° C. Throughout the range 200°–700° C., advantage can be taken of the high speed recirculation of the hot products of combustion. The effective internal dimensions are : 27 ft. $1\frac{3}{4}$ in. long, 25 ft. 6 in. wide, and 21 ft. to the centre of the arch. Four zones are arranged to operate from indicating controllers, each zone having a bank of four vertical flame burners ; these burners are of the internal-mix turbulent type, in which the gas and preheated air for combustion mix tangentially prior to passing into the heating chamber.

The very special and intricate fabrications being treated in this furnace demand accurate control of heating rates ; in this case the actual time-temperature rise is held in accordance with British Standard Code 1500-1949, laid down for fusion welded pressure vessels ; the temperature can be raised at the rate of 100° C. per hour, maximum, throughout the heating period, up to 650° C., at which temperature the fabrications are soaked for a period of 8–10 hours. During this soaking, the temperature differential between the furnace atmosphere and the work being treated steadily decreases.

The normal economic load for stress relieving is 60 tons and, under actual production conditions, tests indicate that to heat to a temperature of 650° C. and soak—the total time cycle being 17 hours—the overall

fuel consumption is under 4,500 cu. ft. of town's gas per ton of welded fabrications treated.

A very different design is the portable-cover furnace shown in Fig. 10, recently installed at the works of Messrs. R. B. Tennent, Ltd., for the long cycle heat treatment of mill rolls in the temperature range 350°–600° C. The internal dimensions of the hood are 8 ft. 9 in. wide, 28 ft. long, and 8 ft. high from hearth level to crown of arch. The maximum charge for which this furnace is designed is 70 tons. In this case also, accuracy and uniformity of temperature is vital, and to obtain the required limits, a hot gas recirculating system is incorporated. Below hearth level there are two large capacity hot-gas fans, each having a gas fired combustion chamber at the inlet. From the fans the hot gases pass into a system of ducts in the hearth brickwork, and enter the furnace chamber through a large number of vertical ports distributed over the whole of the hearth area, with

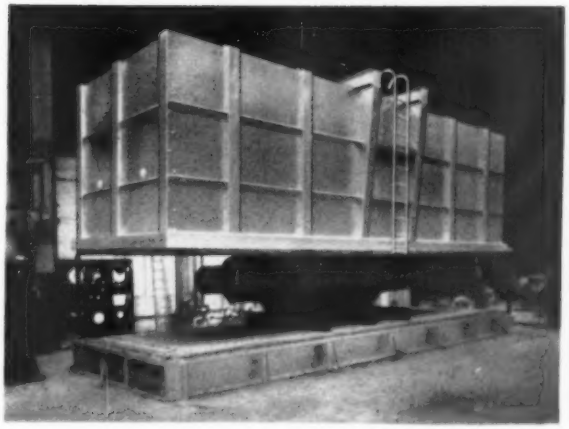


Courtesy of John Mathison, Ltd.

Fig. 9.—A Mathison universal stress relieving furnace.

the exception of the centre portion, where return ports are situated leading the gases back to the combustion chamber. Each combustion chamber is direct fired by one air-blast burner fitted with electric ignition and flame failure safety equipment. Honeywell Controls fully-proportioning temperature control is incorporated, with pneumatic operation of the control valves by power cylinders.

Several continuous conveyor furnaces have been installed for stress relieving to replace with advantage the batch furnaces usually employed for this process. A typical instance is the furnace shown in Fig. 11, which is being used for the treatment of transformer laminations. The laminations are placed on the conveyor in shallow stacks and are carried through a predetermined heating and cooling cycle, ensuring that they all receive identical treatment which can be repeated as desired. As steel spacers are not required, the charge weight is



Courtesy of Dowson and Mason, Ltd.

Fig. 10.—A portable cover furnace recently installed by Messrs. R. B. Tennent, Ltd., for long cycle treatment of mill rolls.

reduced. The shorter treatment time leads to savings in power consumption and minimises carbon pick-up, so permitting the use of an inexpensive atmosphere derived from town's gas.

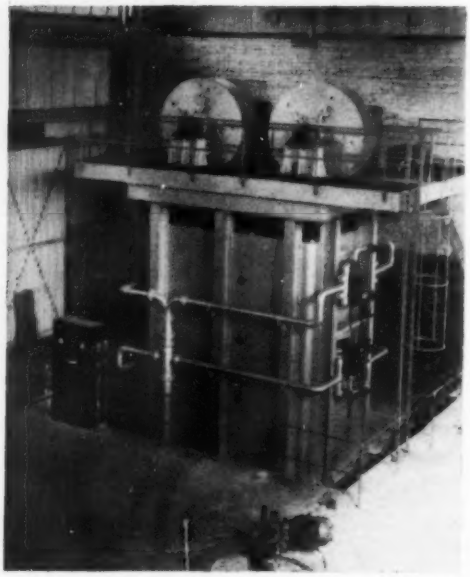
The furnace provides temperatures up to 1,050° C., but the normal operating temperature is 820° C., and the average treatment cycle is 60 minutes. The length of the furnace is made up of a preheating chamber, in which the laminations are purged of oxygen, a heating chamber divided into independently controlled zones, a slow cooling section, and a water cooled section to bring the work to a temperature at which it can be allowed to leave the protective atmosphere. Power consumption per ton of laminations treated in the furnace averages 300 kW.; gas consumption is between 2,800 and 3,000 cu. ft.; and consumption of water for cooling about 370 gal.

Annealing and Normalising

As in the case of hardening, tempering, spheroidising, and patenting, normalising and annealing involve no change in the composition of the material being treated,

Courtesy of Royce Electric Furnaces, Ltd.

Fig. 11.—One of several continuous conveyor furnaces for stress relieving transformer laminations.

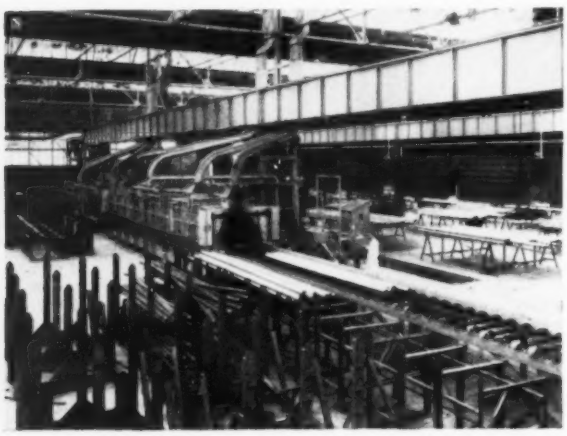


Courtesy of International Furnace Equipment Co., Ltd.

Fig. 12.—A continuous chain normalising furnace installed at the works of Brown, Lenox and Co., Ltd.

and are sometimes referred to as the true heat treating processes. The normalising process is commonly applied to steel articles of heavy section, which are heated to a temperature a little above the critical range and subsequently cooled in still air. The process is used to restore the steel to its normal condition after hot-working, cold-working, non-uniform cooling or overheating, or it may be used to remove the effects of previous heat treatments. Stresses are relieved and the grain size and structural constituents of the steel are affected by this process. Annealing is a broader term and is usually employed to soften the material treated.

A typical product involving the application of a normalising treatment is cable chain, and the furnace shown in Fig. 12 was recently installed for the continuous normalising of sizes of cable chain ranging from 4 in. to $1\frac{5}{8}$ in.



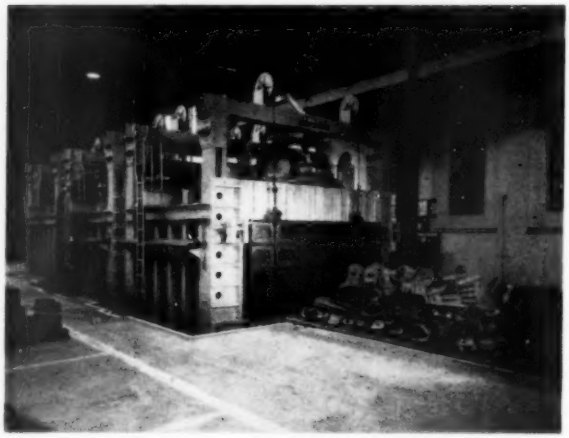
Courtesy of Birlec, Ltd.

Fig. 13.—A continuous roller hearth furnace for the treatment of stainless steel tubes.

at a production rate of 1 ton per hour, in close collaboration with Messrs. Brown Lenox and Co., Ltd., Pontypridd.

The chain for treatment is suspended in the furnace chamber in the form of a loop from two power-driven drums fitted above and each side of the furnace chamber. These drums, coupled together with a common variable speed drive, carry the chain through the two zones of the heating chamber at a predetermined speed depending on size. Initial starting-up and feeding-in of chain is achieved by a special de-clutching arrangement on the drive, which allows the ingoing side drum to be driven separately to hoist the heavy chain up the side of the furnace to the level of the top opening.

The furnace chamber, in the form of a vertical tunnel with the exhaust duct at the bottom, is fired by means of eight Schieldrop self-proportioning town's gas burners, positioned on the sides and arranged for control in two zones in such a way as to ensure that the chain is fully soaked to the required temperature on leaving the furnace chamber. The burners, arranged in pairs, are controlled by two Cambridge automatic temperature regulators operating through Cambridge valve positioners giving



Courtesy of G. P. Wincott, Ltd.

Fig. 14.—A triple chamber furnace for annealing loads up to 20 tons per chamber. It forms parts of the installation in the new heat treatment department of the steel foundry division of Edgar Allen and Co., Ltd.

high/low fire for control of temperature. A Cambridge two-point recorder is also provided. When heating chain in this furnace to a temperature of 880° C., to give a satisfactory structure, at the rate of 1 ton/hr., the average fuel consumption is 6,000 cu. ft. of town's gas per hour.

An installation of basically conventional type, but with special features representing new developments, is the continuous roller-hearth conveyor furnace for annealing stainless steel tubes. This furnace, shown in Fig. 13, is heated directly by gas fired burners having a total rating of 6,750 cu. ft./hr. of town's gas, controlled in four separate zones and capable of heating 1 ton of tubes per hour to a temperature of 1,500° C. The interesting features of this equipment concern the drive arrangements for the roller-conveyor track, and the provision for rapid cooling of the work, as it emerges from the heating chamber, by direct water or air quenching through pressurised jets. The conveyor rollers are driven through a variable speed device and by means of electro-magnetic

clutches. At normal speeds, tubes can be moved from the loading table into the heating chamber; tubes may then be held in the heating chamber for a determined period, during which the rollers are oscillated instead of being continuously driven, in order to avoid distortion due to a continuous unidirectional load at full temperature. Finally, a high speed drive is provided to transfer the work quickly from the heating chamber to the quenching chamber. This furnace is, in fact, arranged for operation on the batch principle, but with the advantage of a completely mechanised and automatic work transfer system.

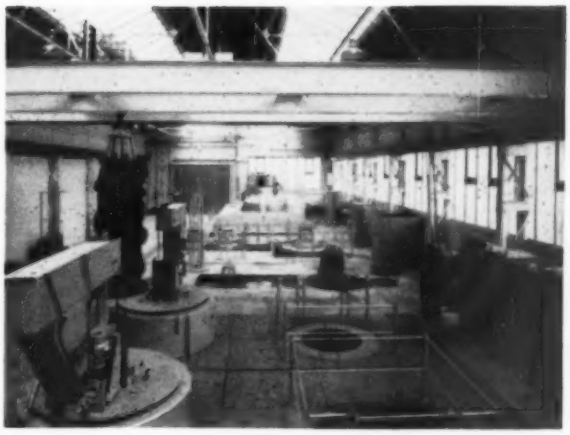
The latest Brayshaw general heat treatment furnace—the Hynor—is a natural draught design unit capable of operating in the temperature range 650°–1,200° C. without the use of pressure air. It can be arranged for gas and air-blast firing or, if required, can be supplied with low-capacity burners enabling temperatures in the region of 450°–650° C. to be obtained. Each natural draught burner is fitted with controls for town's gas and induced primary air, whilst a main quadrant valve is fitted to control the general atmosphere of the working chamber. Secondary air is admitted through adjustable ports on each side of the furnace and passes to the combustion chamber along refractory lined flues heated by conduction from the combustion passages under the hearth. Sizes range from 12 in. wide × 9 in. high × 18 in. long up to a maximum of 4 ft. wide × 2 ft. high × 7 ft. 6 in. long.

Of special interest among recent developments are installations in the new heat treatment department in the steel foundry of Edgar Allen and Co., Ltd. The furnace installation comprises two triple chamber furnaces, a circular furnace and a single-chamber tempering and quenching furnace, all designed for the use of town's gas. One of these triple chamber furnaces is shown in Fig. 14; it will treat loads of castings up to 20 tons per chamber. This unit consists of three chambers, each 11 ft. 9 in. long, 10 ft. wide and 5 ft. 8 in. high, and each accommodating a bogie and fitted with two gravity self-sealing type doors. The castings are heated from cold to 500° C. in the first chamber, charged into the second, where they are taken up to 920° C., and finally cooled in the third chamber. The sensible heat from the cooling charge is used to preheat the combustion air for the heating chamber. A prescribed heating and cooling curve is automatically maintained by furnace temperature and pressure controls, and flow indicators and recorders for both air and gas.

As some of the annealing work is dimensionally too big for the triple chamber annealing furnace, it was decided to build a special furnace for this range of work, and at the same time make the chamber capable of being extended in height for exceptionally tall work. This unit consists of a fixed circular section 12 ft. 6 in. internal diameter by 5 ft. 3 in. high, with its top flush with the shop floor. The two removable sections are 2 ft. 6 in. high, and with them the chamber can be made 7 ft. 9 in. or 10 ft. 3 in. high. The roof is domed and will fit any section.

To complete this development a single chamber bogie hearth furnace is being built for tempering castings after quenching, and for handling work which is too large for the triple chamber quenching furnace. The problem of providing a furnace capable of operating from 250° C. for tempering and up to 1,050° C. for quenching is being tackled by applying an indirect form of heating.

New wire heat treatment plant installed in the new

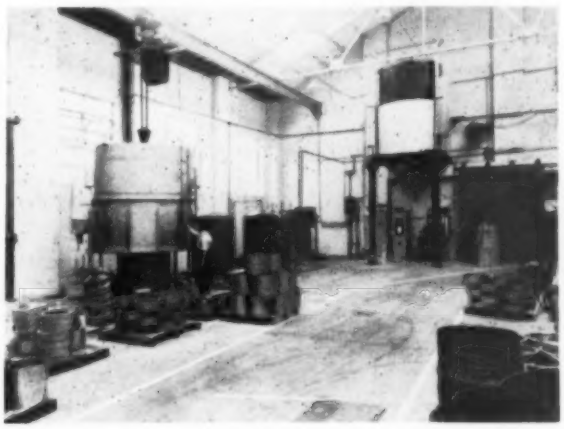


Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 15.—The wire heat treatment plant installed in the new Kingsfield works of Darwins Bright Steels, Ltd.

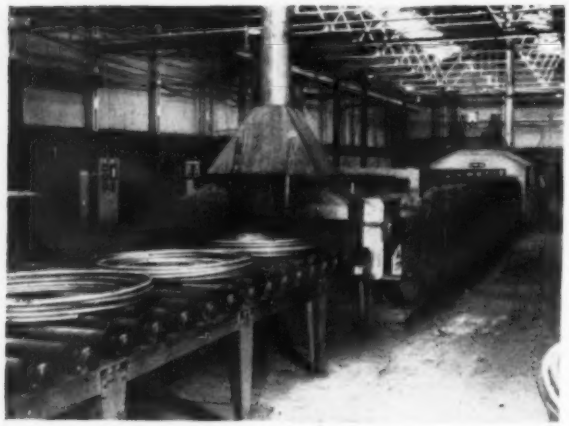
Kingsfield Works of Darwins Bright Steels, Ltd., includes an electrically heated pit furnace for spheroidising and straight open annealing; two electrically heated pit furnaces for normalising, hardening and tempering; and a pit pot furnace for either bright or open annealing. The complete installation is shown in Fig. 15.

The spheroidising furnace provides an operating temperature of 800° C., and a typical spheroidising cycle consists of heating the charge to this temperature, soaking for two hours, cooling in the furnace to 720° C., followed by a further four hours soaking, and finally cooling to 550° C. before discharging. Forced air circulation is provided by a fan fitted to the lid of the furnace, and the air flow is confined by an inner cylindrical baffle to a path over the elements and through the charge. The baffle is 8 ft. in diameter, giving an effective loading space of 7 ft. 6 in. diameter by 8 ft. deep. The average weight of charge is 3 tons. The lid, of the lift-and-swing type, is electrically operated and controlled by means of push buttons mounted on a separate switchgear cubicle. The furnace is rated at 350 kW. and the elements are arranged in three independently controlled zones.



Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 16.—A bell furnace installation for bright annealing nickel silver strip and wire in coils.



Courtesy of G. W. B. Furnaces, Ltd.

Fig. 17.—Discharge end of a driven roller hearth electric furnace for bright annealing copper tube in coils.

A new bell furnace installation, shown in Fig. 16, is being used for bright annealing nickel silver strip and wire in coils. Each of four furnace bases will accommodate a charge up to 3 ft. in diameter by 3 ft. high, a typical load weighing about 15 cwt. The charge, sealed in a hood, is protected by an atmosphere of cracked ammonia after purging with burnt ammonia. This installation will give an output of approximately 4½/5 cwt./hr.

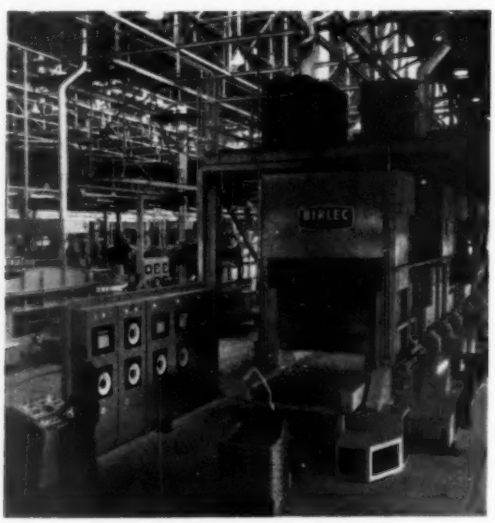
A notable installation, which is nearly 150 ft. long, is shown in Fig. 17 ; it consists of a driven roller hearth furnace and is used for annealing copper and brass tubes. These tubes are treated in straight lengths up to 35 ft., the outside diameter ranging from ¼ in. to 4 in.: beyond this length the tubes are coiled up to a maximum length of 60 ft., forming coils 5 ft. 6 in. diameter, which are also passed through the furnace. The unit is designed for an output of 2 tons/hr. of annealed tube. A protective atmosphere is used within the furnace so that the copper tubes emerge from the discharge end quite bright, while brass tubes have a good, clean finish, thus eliminating the pickling process. Consumption figures, obtained during actual operation, show that the electricity required is 91 kWh./ton for tubes annealed in straight lengths, while this figure is slightly greater for tubes in coil form. Gas consumption from an exothermic plant is approximately 950 cu. ft./ton. The total rating of 285 kW. is divided into three zones, arranged longitudinally along the furnace, each of which is controlled independently and automatically by an Electroflo electronic indicating controller, while a 3-point recording instrument gives a permanent indication of thermal conditions along the length of the furnace.

Further additions have been made to the annealing shop at the Margam works of The Steel Company of Wales, Ltd. The extensions now completed, involving seven furnaces and eighteen bases, have brought the installation up to twenty-nine furnaces and seventy-eight bases, with an output of 17,000 tons a week. As will be noted in Fig. 18, these furnaces are used for annealing strip in the form of coils. They are heated by specially designed radiant bowl burners, which give complete combustion and automatic control at all times in the heating cycle. The high velocity of the products of combustion maintains a highly turbulent atmosphere between the inner cover and the furnace wall, which in turn gives rapid heat transfer. An automatic balanced pressure system of waste gas discharge is maintained within critical limits during the heating cycle. Each furnace base will take four stacks of coils. Special convector plates are placed between the coils, and the heat is transmitted to the edges of the strip by high velocity gases passing through the plates. Each furnace base has four high velocity fans which induce this recirculation. The complete plant is fired by coke-oven gas.

A cycle-annealing furnace installed at a tractor works for the heat treatment of forgings (Fig. 19) has the roller track arranged in separately driven sections which may be run at either high or low speed, the low speed being adjustable according to loading conditions. The track incorporates a loading table, a heating chamber, a rapid cooling section, a slow cooling or holding section, a water

Courtesy of The Incandescent Heat Co., Ltd.

Fig. 18.—A further seven furnaces and eighteen bases have been added to the annealing shop at the Margam works of The Steel Company of Wales, Ltd.



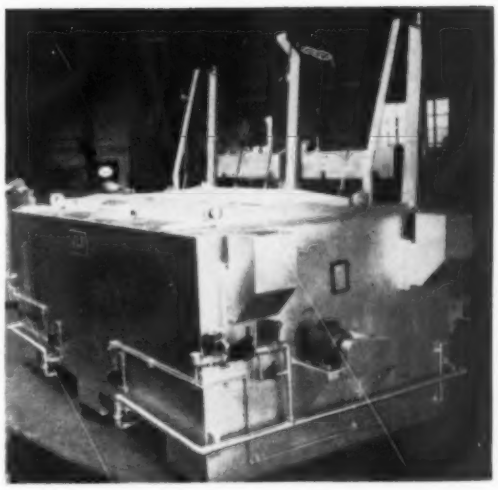
Courtesy of Birlec, Ltd.

Fig. 19.—Roller hearth furnace for the cycle-annealing of forgings in a tractor factory.

jacketed cooling section, and a final cooling section of the spray quench type leading to a discharge table. Motor-operated doors are provided at the entrance and discharge ends of the heating chamber, and at the final discharge point, these doors being automatically operated as work trays approach them. The presence of a work tray in front of the door is detected by a photo-electric device, and when the door opens the roller conveyor is switched to high speed in order to transfer the tray promptly to the next section. This arrangement permits alternative treatment cycles to be followed automatically by presetting appropriate controls.

During the past year, furnaces incorporating the J.L.S. system of air circulation have found a steadily increasing number of applications, including the treatment of beryllium-copper and titanium. Among the various designs successfully applying this system of air circulation, mention may be made of a top-loading furnace recently installed for the treatment of special high carbon steels. This furnace, shown in Fig. 20, has a working space 10 ft. long, 4 ft. wide and 4 ft. deep, and the entire interior of the furnace is of 10 gauge heat-resisting steel. The 8 in. insulation is of graded mineral wool form, ensuring high thermal efficiency with a low thermal storage value. Two 24 in. fans provide an air circulation of 10,000 cu. ft./min., providing temperature uniformity throughout the entire working space. The heat exchangers built into the furnace are completely sealed, giving a perfectly clean atmosphere around the charge. The maximum operating temperature of this unit is 750° C., and firing is by town's gas, although electricity or oil may be used.

Forced circulation of air has been applied in furnaces operating at relatively low temperatures for many years, but it is now being applied at high temperatures. Such a furnace has been developed by Hedin, Ltd., to meet the exacting requirements of Messrs. Rolls Royce, Ltd.,—maximum temperature variation of ± 10° C. at 1,100° C.—for the treatment of sizeable jet engine components, such as silencers and thrust reverser parts, for Rolls Royce "Avon" and "Conway" jet engines, and for "Tyne" turbo-propeller engines. As will be noted in Fig. 21 this is a typical box-type furnace with effective internal dimensions 4 ft. 6 in. by 4 ft. 6 in. by 5 ft., with a rating of 210 kW. Nickel-chromium heating elements are supported in the roof and side walls of the heating chamber. Four fans, fabricated from Nimonic 75, provide the forced circulation of air or protective atmosphere. Each fan is mounted on a tubular shaft of similar material, and is supported outside the furnace in two standard ball bearing plummer blocks. Inside the tubular shaft is inserted another Nimonic tube through which compressed air is guided. This flows to the end of the shaft in the furnace and reverses direction to flow back through the annular gap between the tube and the outer tubular shaft. This system of cooling prevents the shaft at the hot end from exceeding 800° C., and enables the Nimonic material to maintain its strength at the elevated temperatures, up to 1,100° C., in the furnace. The four shafts are driven by a small motor which provides two speeds: 1,700 r.p.m. up to 800° C., and 850 r.p.m. up to 1,100° C.: the changeover is fully automatic. The temperature control is by voltage regulation, actuated by a potentiometric control, enabling the furnace to be operated at any temperature from ambient to 1,100° C. This plant was tested, under the supervision of Rolls Royce engineers, before despatch to Brazil, and the



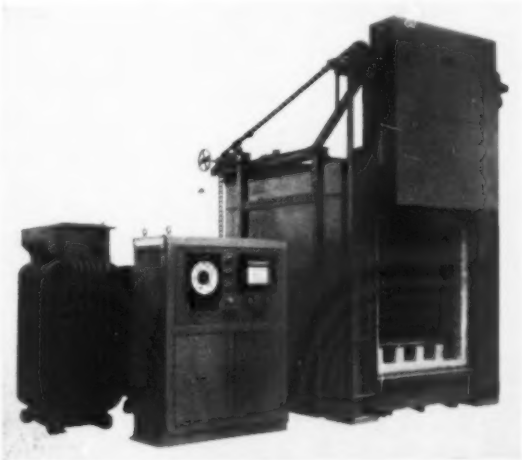
Courtesy of J. L. S. Engineering Co., Ltd.

Fig. 20.—A top loading furnace used for the treatment of special high carbon steels. A feature is the air circulating system.

temperature variation was found to be ± 5° C. at 750° C., and to be negligible at 1,100° C. A second furnace has been ordered by Messrs. Rolls Royce, Ltd., for use in Argentina.

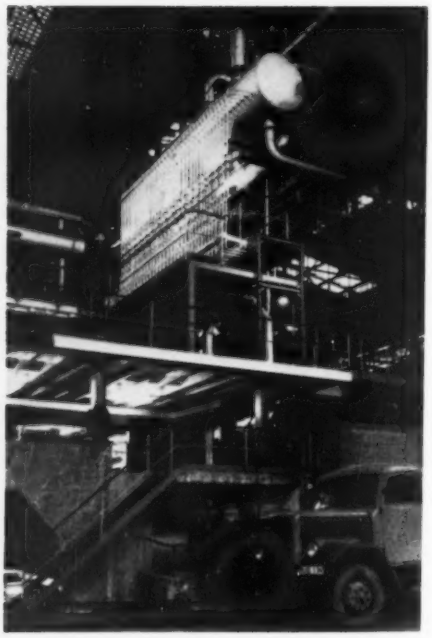
On many metallurgical furnaces, a significant fraction of the heat input is lost to cooling water. This waste heat may be recovered in the form of saturated steam at any desired pressure, by supplying the water cooled part with boiler feed water, allowing the pressure and temperature to rise, and thus to form steam in a suitably placed collector drum. This method has been developed and established by Reining-Heisskulung of Mulheim/Ruhr in Germany, and is now being applied in this country by Stein and Atkinson, Ltd.

The system is particularly suitable for application in the case of units using large quantities of cooling water,



Courtesy of Hedin, Ltd.

Fig. 21.—A box-type forced air circulation furnace for operating at 1,100° C.



Courtesy of Stein and Atkinson, Ltd.

Fig. 22.—A steam drum adjacent to a continuous furnace to recover heat lost to cooling water.

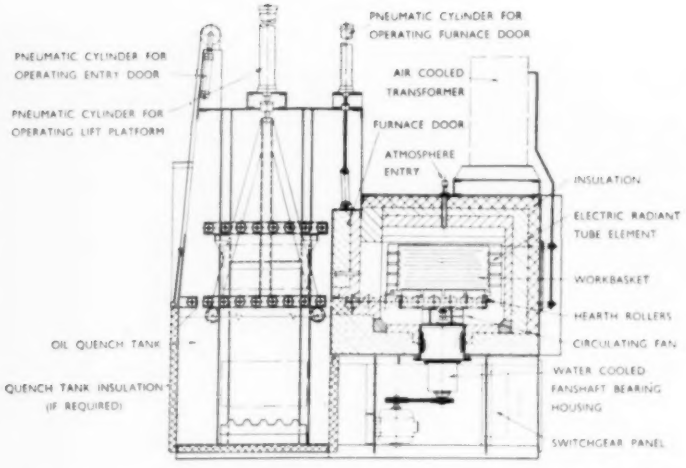


Fig. 23.—Line drawing showing the general construction of the Wild-Barfield sealed quench furnace.

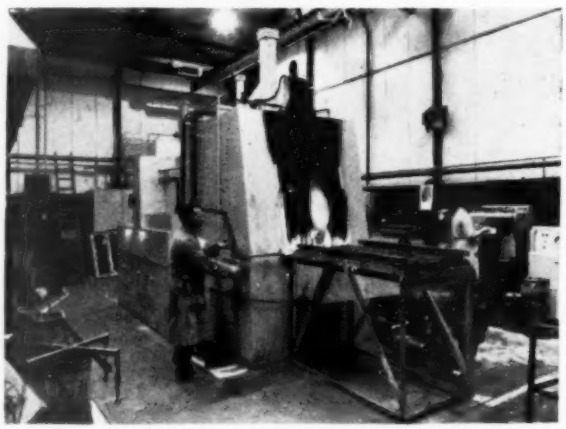
such as open hearth furnaces and blast furnaces, but it is also being applied in connection with the cooling of the skids of large multi-zone continuous reheating furnaces, where boiler feed water is circulated at high velocities through the skids and skid supports by suitable pumps. Steam is formed in collector drums placed conveniently to the furnaces. In a typical case of a 100-ton hr. continuous furnace, steam production is up to 20,000 lb. hr. at any given pressure. As well as the obvious benefit of a substantial steam production, from what would otherwise have been waste heat, the life of the skids is prolonged, due to the high quality of the water used for cooling. A typical installation of a steam drum adjacent to a continuous furnace is shown in Fig. 22.

Carburising and Nitriding

Of the more recent furnace developments, that of the sealed-quench equipment is probably the most important, enabling clean carburising, hardening, etc., to be undertaken on a semi-continuous basis, the quench itself being within the furnace structure and protected by the atmosphere in use. Such sealed-quench furnaces may be of the single-ended or straight-through types, the latter being preferable where flow line methods of production prevail. The general arrangement of this design is shown in Fig. 23, and Fig. 24 is an illustration of a straight-through type in service. Heating elements take the form of radiant tubes which are specially designed for operations involving carburising gases. Not only do these provide all the advantages of electric heating, but they may be replaced at any time without disturbing the atmosphere conditions within the furnace. The atmosphere control panel comprises flowmeters and valves for butane or propane, ammonia and endogas, the latter being supplied in this installation by a G.W.B. endothermic generator. Temperature control is effected by a recording controller. The quench tank is provided with a suitable cooling and quenchant agitating system, in which a pump circulates the oil through an external cooler. In operation, the equipment follows the accepted cycle, interlocks being incorporated to ensure proper working.

Metallurgical and production advantages associated with gas carburising have led to the increasing use of this method, whether by generated gas or by the drip feed system. Furnaces with fans in the base and others with fans in the top are now in general use. A typical installation of top-fan carburising furnaces which make use of Carbodrip as a liquid medium is shown in Fig. 25.

To meet the need for gas carburising in small scale production and in the laboratory, a small electrically heated, vertical furnace has been introduced, as shown in Fig. 26, one of which has recently been installed in the new works of the British Tap and Die Co., Ltd. This furnace provides for temperatures up to 1,050° C. in a gas-tight retort of heat-resisting steel, having a work space 10 in. diameter and 12 in. high. The heating elements are of heavy gauge nickel-chromium wire,

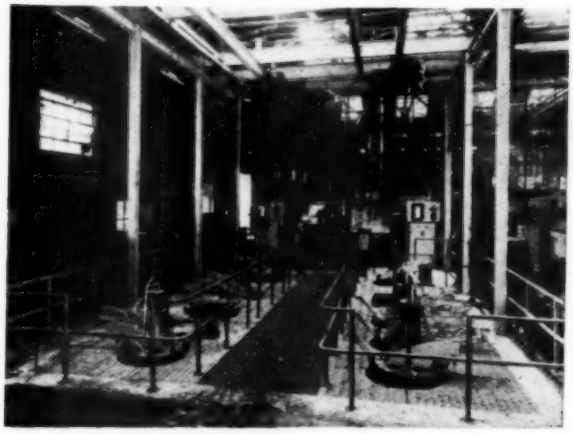


Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 24.—Sealed quench equipment enabling clean carburising to be undertaken on a semi-continuous basis.

mounted in coil form in grooved refractory tiles surrounding the retort. To provide easy and rapid operation, the mouth of the retort is sealed with a plug lid fitted with a hand-operated power-jack and swivel mast. In the closed position a sealing lip on the lid engages in an annular seal in the retort. In the base of the retort a heat-resisting steel fan, driven by motor, provides rapid circulation of the carburising gas to ensure uniform temperature distribution and depth of carburising. A heat-resisting steel basket carries the charge of taps and dies to be treated and, in the furnace illustrated, the carburising atmosphere is generated within the retort from a special fluid introduced by the drip-feed technique.

An installation of six gas carburising furnaces of the vertical cylindrical type, with separate cooling chamber, has recently been completed (Fig. 27). Each furnace has a maximum rating of 100 kW., and takes a charge basket 25 in. inside diameter by 54 in. deep. These furnaces are capable of operating continuously at a temperature of 1,000° C., and the carburising atmosphere is generated within each furnace from hydrocarbon drip-



Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 25.—Installation of Carbodrip feed gas carburising furnaces of the top fan type.

feed units. The furnace lids are operated pneumatically to facilitate rapid transfer of a charge from a furnace to a cooling chamber.

Several furnaces have recently been supplied by the Electric Resistance Furnace Co., Ltd. and installed in the Cumbernauld Works of Burroughs Adding Machines, Ltd. These include an Efco-Lindberg multi-purpose furnace, two horizontal batch furnaces, an Efco-Lindberg batch type cyclone furnace, a rotary tube furnace, an Efco-Upton continuing graphite electrode salt bath and an endothermic atmosphere generator. The multi-purpose furnace, which is shown in Fig. 28, is used for carburising and carbonitriding, and is electrically heated by Corrtherm elements. It is rated at 50 kW. and provides temperatures up to 950° C., with a loading space 24 in. wide, 36 in. deep, and 15 in. high. As described in an earlier review, this design of furnace has an enclosed oil quench and cooling chamber, so that a charge may be direct quenched or slow cooled out of contact with air. The quench tank has a capacity of 500 gal. and is equipped with oil agitator and oil cooling equipment.

The automotive industry has always been ready to

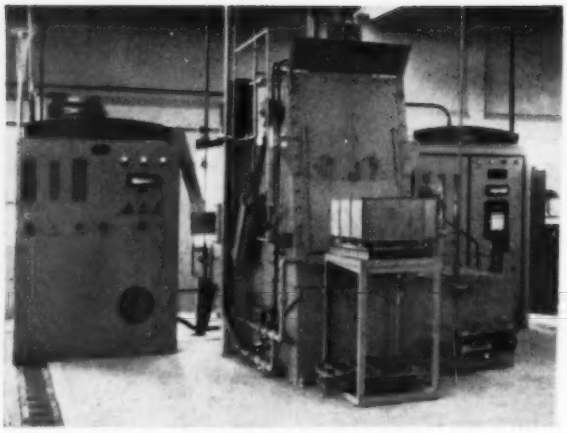
Courtesy of Royce Electric Furnaces, Ltd.

Fig. 26.—Small electrically heated gas carburising furnace for laboratory or small scale production use.

adopt progressive ideas for mechanised work handling and these are exemplified in a number of continuous gas carburising furnaces designed and installed by Birlec, Ltd., one of which is shown in Fig. 29. These furnaces are heated by transverse, gas-fired radiant tubes, so that the specially prepared furnace atmosphere, of controlled carbon potential, is not contaminated by combustion products. The work is carried on nickel-chromium, grid type trays, which are moved over idle rollers by means of a hydraulic pusher mechanism at the loading end. Passing through heating, carburising and diffusion zones (each with separate temperature control) at speeds controlled according to the desired carburising cycle time, the trays are then lowered into a quenching tank. Alternatively, the trays may be withdrawn through the side of the furnace when the work requires jig quenching. From the quench tank, the trays are elevated and transferred to a return track, where the components are washed free from oil and then tempered in an electrically heated air circulation furnace, from

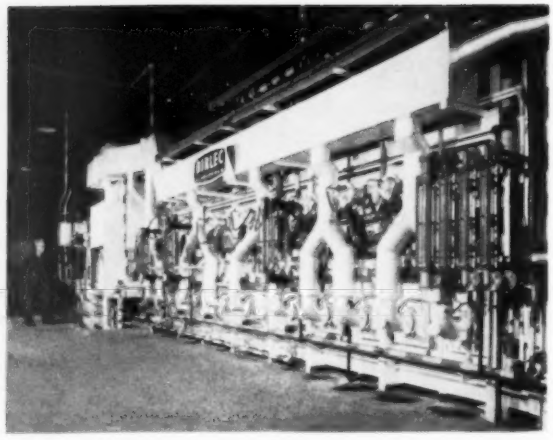
Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 27.—Installation of six gas carburising furnaces of the vertical cylindrical type recently completed.



Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 28.—An Efco-Lindberg multi-purpose furnace installed in the Cumbernauld works of Burroughs Adding Machines, Ltd.

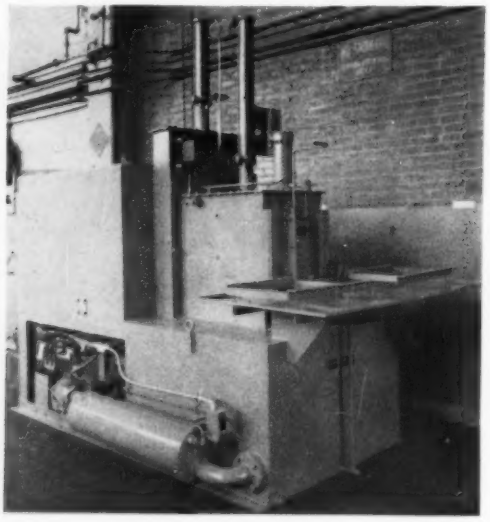


Courtesy of Birlec, Ltd.

Fig. 29.—Side view of continuous gas carburising furnace showing burner and exhaust ends of tube heaters.

which they emerge at the unloading and reloading station adjacent to the charging doors. The loaded trays are handled entirely by automatic transfer mechanisms throughout their journey, and operators are employed only on loading and unloading.

A carburising furnace to a design which is entirely new to this country has recently been ordered from Integra, Leeds and Northrup, Ltd., whose associated American Company has been making and selling furnaces of the same design for a considerable time; increased capacity has now enabled Integra to proceed with the manufacture of furnaces to this design. The method of treatment is known as the Tricarb method, and the furnace applying it can be used interchangeably for homogeneous carburising, controlled case carburising, carbon restoration, hardening or carbonitriding. Heating chamber, protective atmosphere vestibule and quench tank are combined into one compact unit, as shown in Fig. 30. The principle of forced convection is successfully applied, ensuring uniform circulation in the heating chamber. From the time the load enters the furnace until it leaves the quench it is under precisely regulated conditions. During heating and before quenching, both temperature and carbon potential of the atmosphere are automatically measured and controlled directly from the heating chamber. During quenching, temperature controlled oil is forced uniformly through the load by a high-velocity circulation system. The standard dimensions of the heating chamber are 15 in. wide, 24 in. long and 10 in. high, and the temperature range of the furnace is 780°–1,000° C. It is supplied complete with transformer, quench tank with cooling and circulating system, pneumatically operated elevator, Carbohm detector, thermocouple, temperature limit fuse, extension lead-wire and contactor.



Courtesy of Integra, Leeds and Northrup, Ltd.

Fig. 30.—Sealed quench equipment employing the Tricarb method, which has been in operation for some time in the United States but is new to this country.

A further sealed quench furnace recently installed has effective internal dimensions 24 in. wide, 36 in. long and 12 in. high, with an electric loading of 60 kW. This furnace operates with the drip-feed system, both for gas carburising and carbonitriding. It is illustrated in Fig. 31.

Hardening and Tempering

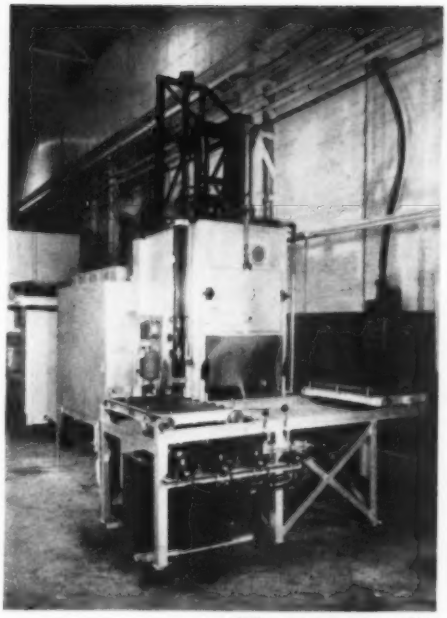
Recent installations of furnaces specially designed for hardening or tempering include the equipment shown in Fig. 32. It is a clean hardening and tempering line for cylinder liners, and comprises a hardening furnace and associated atmosphere plant, charge and discharge tables, degreasing unit with hoist, and a tempering furnace. The hardening furnace is of the controlled atmosphere batch type, with integral purge chamber and quench tank, enabling the work to be heated and quenched under correct atmosphere conditions. This furnace, rated at 60 kW., is designed for use with nickel-chromium work trays, each 36 in. long, 25 in. wide, and a loading height of 15 in., and for operating at temperatures up to 950° C. Three work trays provide for a system whereby, whilst one is being quenched, the second tray is being heated and a third loaded ready for charging. A combined pusher/go-getter mechanism is provided at the

front for charging and discharging, the whole operation being under sequenced control. The gas from a 500 cu. ft./hr. endothermic atmosphere generator eliminates decarburisation during treatment and provides a clean end product. With suitable additions, carburising and carbonitriding may be carried out. After quenching, the components are allowed to drain before being passed into the degreasing tank, after which they pass to the tempering furnace.

The tempering furnace is of the vertical, step-continuous, conveyor type—of double-cased construction, with a centre dividing wall, so that a definite path is formed for the conveyor system—complete with air circulation fans. The furnace is rated at 60 kW. and has a maximum operating temperature of 400° C. The components are placed in jigs to prevent distortion, and the latter are conveyed through the equipment on fabricated trays attached to cross-rods of a parallel chain conveyor system, which pass over large diameter sprockets at the top and bottom of the furnace, the shaft at the top being driven by a motor. The conveyor moves each time at a constant speed, but the interval between each movement is under the control of a variable timer, enabling the cycle to be varied to suit the work, within the limits of the timer. To complete the line, a stripping press is provided, to remove the liners from the jig.

A Birlec installation with unusual features comprises three vertical hardening furnaces specially designed for handling long components which must be quenched vertically to avoid distortion. The furnaces are of the cylindrical, bottom loading type, in which the charge, supported on a special carrier, is hung from a suspension rod passing through the top of the chamber and of sufficient length to permit lowering the work into a quench tank below the furnace mouth. The complete quench tank is mounted on a movable carriage which incorporates a loading station.

Although almost the reverse of hardening and tempering, the operations of solution treating and precipitation hardening call for the use of similar equipment in many instances. An interesting furnace for carrying out these treatments on Nimonic alloys is shown in Fig. 33. A feature of this installation is the high temperature attainable—1,200° C. The working chamber measures



Courtesy of The General Electric Co., Ltd.

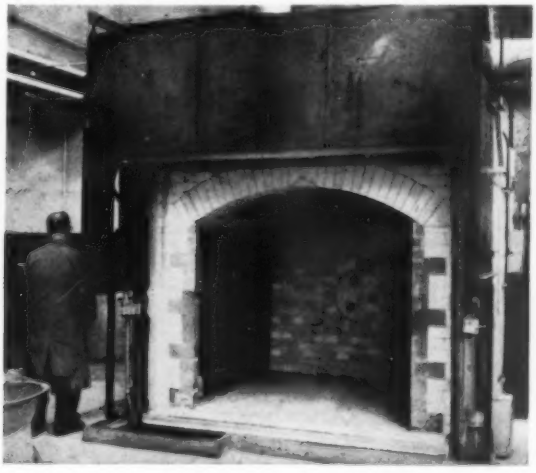
Fig. 31.—Sealed quench furnace which operates with a drip feed system.

5 ft. wide, by 4 ft. 6 in. to the crown of the arch, by 5 ft. from front to back. Forced air circulation is provided for treatment at temperatures in the region of 800°–850° C., the water cooled fan being retracted and replaced by a refractory plug when the furnace is operated at high temperatures.

The latest of a line of sealed quench furnaces developed during the last five years by Thermic Equipment and Engineering Co., Ltd., is gas fired by radiant tubes, and is being applied for clean hardening, carbonitriding, gas carburising or carbon restoration. It is illustrated in Fig. 34, which also includes a completely automatic endothermic generator. This furnace, with its ancillary

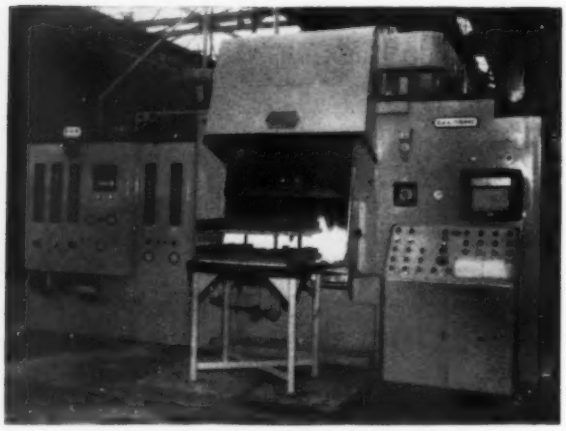
Courtesy of Metalectric Furnaces, Ltd.

Fig. 32.—A clean hardening and tempering line for cylinder liners.



Courtesy of A. R. Wade, Ltd.

Fig. 33.—Forced air circulation furnace for solution treatment and precipitation hardening of Nimonic alloys.



Courtesy of Thermic Equipment and Engineering Co., Ltd.

Fig. 34.—Gas-fired sealed quench furnace for clean hardening, carbonitriding, gas carburising or carbon restoration.

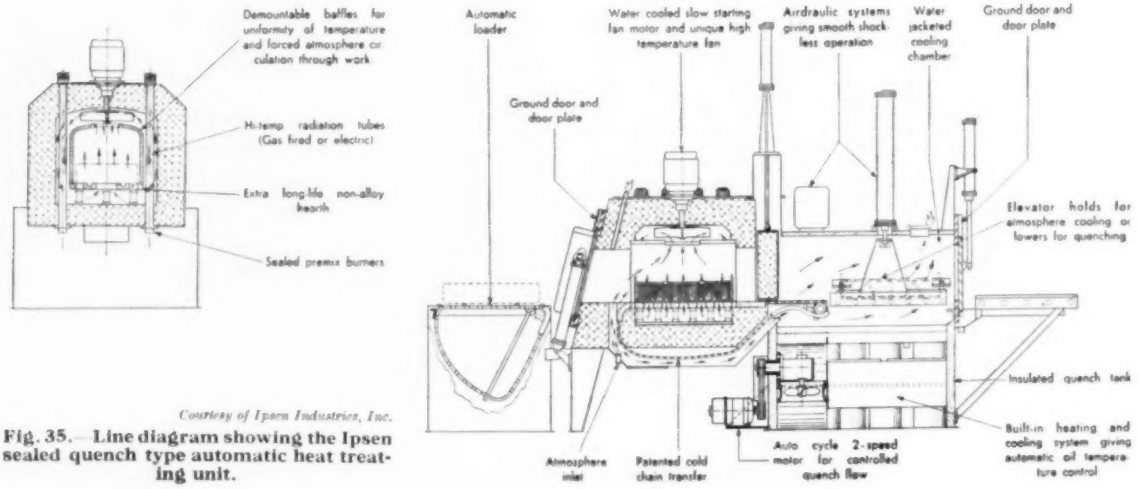
equipment, has all the push button controls of the various items of handling gear placed at a convenient point adjacent to the loading position. The furnace is fired by horizontal U-shaped radiant tubes, each tube being provided with built-in recuperator, capable of preheating the combustion air to approximately 250° C. A built-in ventilating system extracts the products of combustion from the various burners and process fumes created when the vestibule door is opened.

An interesting feature of this furnace is the rapid thermal recovery; for instance, the furnace is heated after week-end shutdown, from warm to 950° C. in under 150 minutes, and, similarly, the furnace temperature of 960° C. is fully recovered in under 30 minutes, when re-charged with a load of 500 lb. Additional output is thus gained at low fuel and radiant tube cost, due to the heavy insulation, recuperated radiant tubes, and a two-year guaranteed tube life.

A notable addition to this year's review are the first installations in this country of Ipsen sealed quench type automatic heat treating units, endothermic atmosphere generators and Dewtronik instruments for dewpoint control. As will be noted in the diagram, Fig. 35, the furnace is of the "straight-through" design, which facilitates automation, increases operating efficiency, greatly helps servicing, and removes the major explosion hazard. Further research in furnace materials and constructions has permitted a recent increase of maximum operating temperature in these units to 1,100° C. The diagram indicates some of the principal features, and worthy of particular note are: (1) properly machined and close fitting outer doors; (2) ceramic radiant tubes with their "sealed in compression" mounting; (3) complete silicon carbide muffle and hearth, and their arrangement with a powerful fan to give directionally controlled atmosphere flow and convection type heating; (4) the "cold chain" rapid load transfer device from furnace to quench elevator—all important door and elevator movements are "Air-draulic" for smooth and consistent functioning; (5) the quenching facilities provide full oil temperature control and hot oil quenching if desired—circulation can be directed fully through the charge, either from below or above as desired, and a two-speed motor with a gear driven propeller gives a maximum circulation of over 4,000 gal./min.; (6) the control panel timers and circuitry provided permit the complete "presetting" of furnace time and all quench details, which then occurs automatically without operator attention.

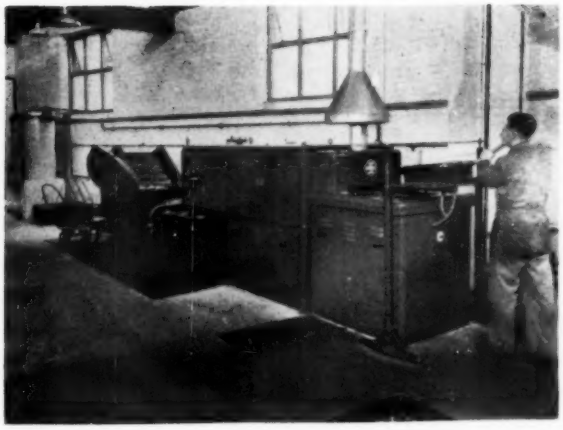
These units allow consistent operation within very tight specification limits, and maintenance costs are low. The overall support of the silicon carbide hearth makes possible the use of Inconel "skid" type baskets which give long service life. These lightweight baskets, and the load carrying qualities of the hearth construction, permit a ratio of useful load to gross load as high as 94% up to the highest temperatures. Units of this basic design are available in a range rated from 25 to 2,500 lb./hr. output.

Shaker hearth furnaces for the heat treatment of small steel components are widely used, but a recent installation for the hardening and tempering of high tensile bolts is of interest. The plant, shown in Fig. 36, deals continuously with an output of 250 lb./hr. It comprises an electrically heated hardening furnace of 45 kW., with a hearth 18 in. wide, and a gas fired tempering furnace,


Demountable baffles for uniformity of temperature and forced atmosphere circulation through work
Hi-temp radiation tubes (Gas fired or electric)
Extra long-life non-alloy hearth
Sealed premix burners
Automatic loader
Water cooled slow starting fan motor and unique high temperature fan
Airdraulic systems giving smooth shockless operation
Water jacketed cooling chamber
Ground door and door plate
Ground door and door plate
Elevator holds for atmosphere cooling or lowers for quenching
Insulated quench tank
Built-in heating and cooling system giving automatic oil temperature control
Atmosphere inlet
Patented cold chain transfer
Auto cycle 2-speed motor for controlled quench flow

Courtesy of Ipsen Industries, Inc.

Fig. 35.—Line diagram showing the Ipsen sealed quench type automatic heat treating unit.



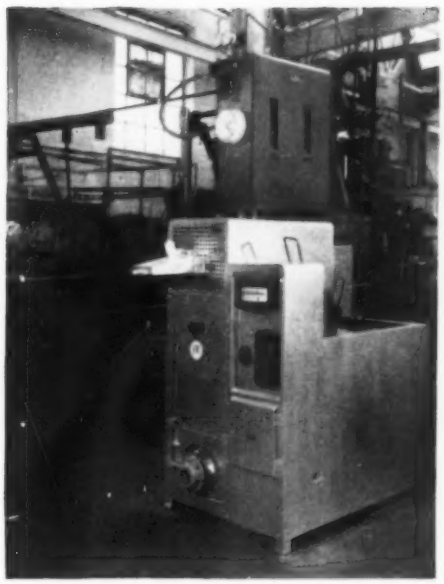
Courtesy of Birlec, Ltd.

Fig. 36.—Shaker hearth continuous hardening furnace for high tensile bolts.

rated at 400 cu. ft./hr., with a 24 in. hearth. Gas firing was adopted for the tempering furnace due to the risk of contaminating electric heating elements by carbon deposited from the cracking of oil carried on the components from the quenching stage of the preceding hardening process. This tempering furnace has sufficient capacity to deal with the output of two hardening furnaces, if required, and is fitted with a powerful atmosphere circulating fan to provide rapid convection heating. Both hardening and tempering furnaces discharge into quench tanks, from which continuously running conveyors extract the work, the quenching oil being continuously circulated and cooled. A protective atmosphere is maintained in the hardening furnace from an exothermic generator.

The demand for bright hardening is increasing for all sizes of components, and this has led to further developments with the sealed quench type of furnace. A new design is that shown in Fig. 37, which has been developed for bright hardening inner races, balls and outer races for miniature ball bearings in a protective atmosphere of raw town's gas and ammonia. The heating chamber, carrying nickel-chromium heating elements, contains a heat-resisting retort with an opening in the floor at the exit end. This opening is directly over a sealed quench chute, the lower end of which is below the surface of the quenchant in a built-in tank. A circulating pump is provided to agitate the quenching oil. The work carrier is of the slipper type and hinged : it is moved by means of a long handle which controls the position of the slipper in the heating zone. At the entry end of the retort, a flap lid enables work to be placed in the slipper. After heating, the rod is pushed fully home and the hinged slipper, being unsupported over the quench chute, precipitates the work into the quench, where it is retained by a catch basket. Temperature control is provided.

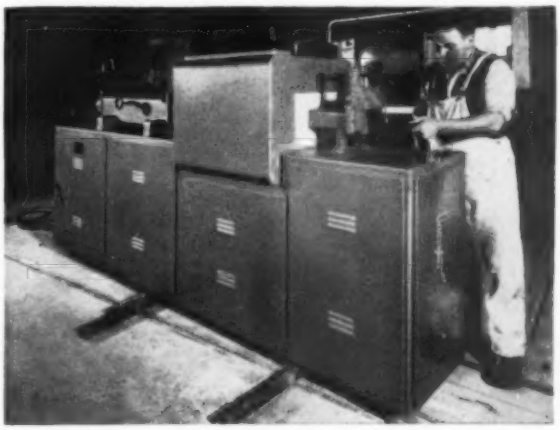
A new controlled atmosphere furnace for the bright heat treatment of photo-electric tube components, installed in the works of the English Electric Valve Co., Ltd., gives closely controlled treatment of small components up to 1,000° C. in a hydrogen atmosphere, and is operated by hand on a definite time cycle. The atmosphere is contained in a gas-tight muffle which runs the length of the furnace. The charge is loaded on trays



Courtesy of Wild-Barfield Electric Furnaces, Ltd.

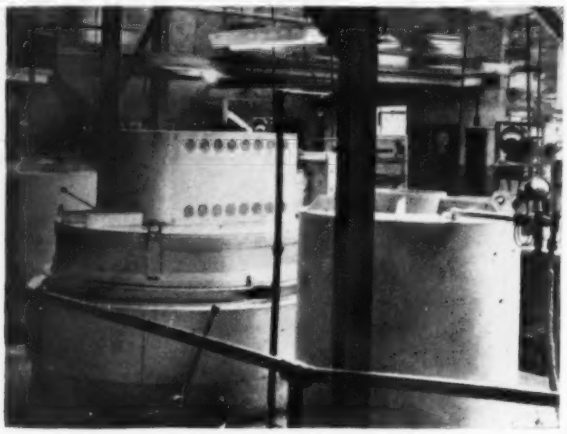
Fig. 37.—Hand-operated sealed quench furnace for bright hardening inner races, balls and outer races of miniature bearings.

and pushed progressively through the chamber to be, in turn, preheated, heated and cooled. At the entrance and exit to the furnace, flame curtains are provided to supply gas automatically through a diffusion chamber immediately a door is opened, to prevent oxygen entering the chamber. This equipment, shown in Fig. 38, is heated by low-voltage nickel-chromium elements suspended in the heating zone external to the chamber, to give free radiation to the muffle. They are graduated to give temperature uniformity and protected by a thermal cut-out. Control gear is housed within the furnace casing, the flow of water is regulated, and gas-flow indicators are fitted for both nitrogen—used as a purging gas—and hydrogen.



Courtesy of Royce Electric Furnaces, Ltd.

Fig. 38.—A new controlled atmosphere furnace for the bright treatment of photo-electric tube components.

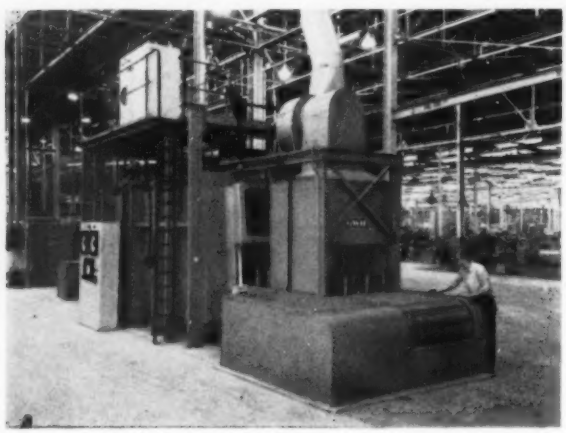


Courtesy of Barlow-Whitney, Ltd.

Fig. 39.—Heavy-duty vertical forced convection electric furnace used for secondary hardening and tempering.

A new series of heavy-duty vertical forced-convection electric furnaces recently introduced by Barlow-Whitney, Ltd., are being used for secondary hardening and tempering. Standard sizes are available to accommodate containers from 12 in. diameter upwards, with a choice of depth to suit requirements. Circulating fans are usually fitted in the base, but on larger units, such as that shown in Fig. 39, they can be incorporated in the top swing cover. Fully automatic control is provided, with the option of a two-point recorder, which can be arranged to control the operation of a timer to maintain the temperature of the furnace within fine limits. Provision is also made to provide the furnace atmosphere to suit particular processes.

A slat conveyor electric tempering furnace recently installed operates at 700° C., and is used for tempering a variety of machined and rough parts, shafts and gears. To cope with the variety of components, the slat type of conveyor was preferred. This comprises a series of cast heat-resisting plates carried by link chains, providing a flat, even surface. The furnace, which is rated at 150 kW. in three independently controlled zones, provides for an output of 1,000–1,200 lb./hr. The effective width over the slat conveyor is 48 in., and the usable height through the furnace is 24 in., the total length of the installation being over 30 ft. To obtain temperature uniformity and to assist in heat transfer from the elements to the charge, three air-circulating fans are fitted in the furnace roof, providing forced convection necessary at the normal operating temperature range of 150°–700° C. As will be noted in Fig. 40, this furnace is designed for production line arrangements.

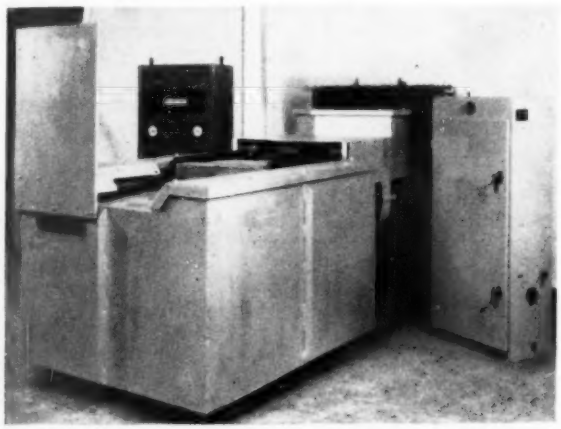


Courtesy of G. W. B. Furnaces, Ltd.

Fig. 40.—A slat conveyor furnace for tempering various types of machined and rough components.

Salt and Lead Bath Furnaces

Although the majority of salt bath furnaces are fired by gas or oil, the use of electric heat for this purpose is making rapid progress. Long life between shutdowns for overhaul of these furnaces is being realised by using immersed electrodes, by means of which low tension current is passed through the salt. Standard furnaces up to 48 in. by 18 in. by 24 in. are already available, but there is no limit to the size of furnaces which can be constructed when immersed electrodes are used for heating. Metal pots are necessary for carburising salts containing cyanide, but neutral salts are used in ceramic lined furnaces. A typical Cassel/Ajax furnace is illustrated in Fig. 41. This is ceramic lined and fitted with a patented design of removable submerged electrode, which can easily be replaced without disturbing the lining. A special design of ceramic block has been developed which increases the lives of electrodes appreciably by protecting them from the combined action of salt and air. Because of the long life and high output per unit of floor space, these furnaces are particularly suitable for use under



Courtesy of Imperial Chemical Industries, Ltd.

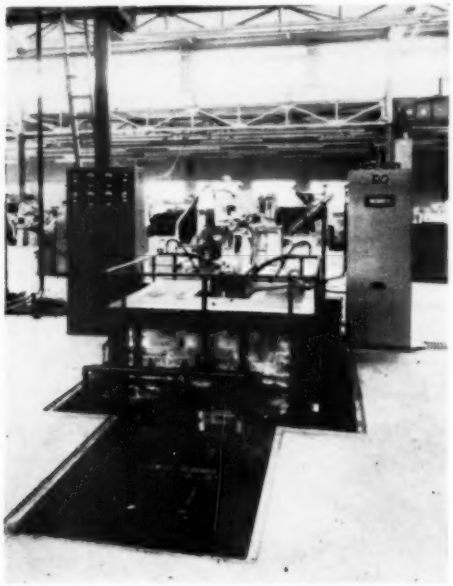
Fig. 41.—A Cassel-Ajax salt bath furnace fitted with removable submerged electrodes.

conveyors for heating for austempering or martempering, resulting in improved physical properties and reduced distortion. A new use for salt baths is in the annealing, after use, of large colliery chains and hooks at 650° C.

Salt baths have, for many years, been successfully used for hardening high speed steels, and in Fig. 42 is shown an Efco-Upton graphite electrode design. In this type, the consumable submerged electrodes are continuously renewable. As the ends within the bath burn away, the electrodes are pushed further in by a screw

mechanism, and when an electrode is nearly consumed another is screwed into its external end. The bath provides working dimensions 18 in. long, 12 in. wide, and 22 in. depth of salt. It is rated at 100 kW. and provides temperatures up to 1,400° C.

In addition to the home market, Kasenit, Ltd., have supplied a number of salt bath furnaces for service abroad, and have many orders on hand for the export market. These are designed for gas or oil firing.



Courtesy of Electric Resistance Furnace Co., Ltd.

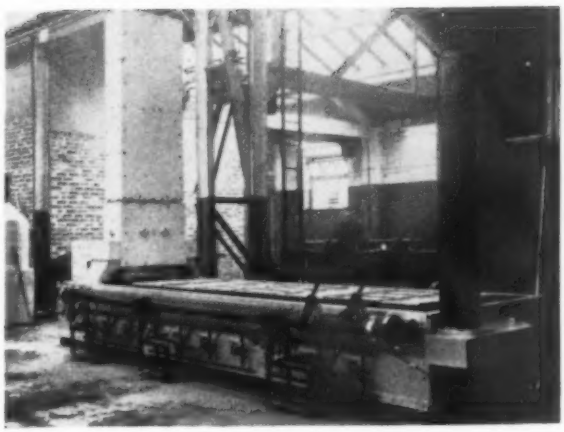
Fig. 42.—An Efco-Upton continuing electrode salt bath.

The original method of treatment in a lead bath is still practised to a considerable extent. A recent installation of this type, shown in Fig. 43, is designed for the continuous blueing of steel strip, and is heated by town's gas. The furnace carries a pot 15 ft. long, 30 in. wide and 12 in. deep, and is fitted with a vertical holding muffle chamber in which the strip is heated. The double case tower accommodating the mild steel muffle is heated by the waste products of combustion. An adjustable air intake is connected to the inside of the muffle to allow a controlled free flow of air from the muffle for the purpose of oxidising the strip. The muffle is sealed at the base by being immersed in the lead. Mild steel asbestos lined removable covers in six sections are arranged on top of the pot.

Induction Heating

That induction heating applications continue to develop is not surprising, because the technique is clean, efficient, fast and flexible; the heat can be precisely controlled and consistent results are obtainable. Not only is this form of heating being applied for heating billets for rolling, piercing and forging, but also for such processes as hardening, annealing, brazing and soldering.

One of the most exacting applications is the reheating of steel billets for rotary piercing as part of the manufacture of solid drawn tubes. To keep the wall thickness

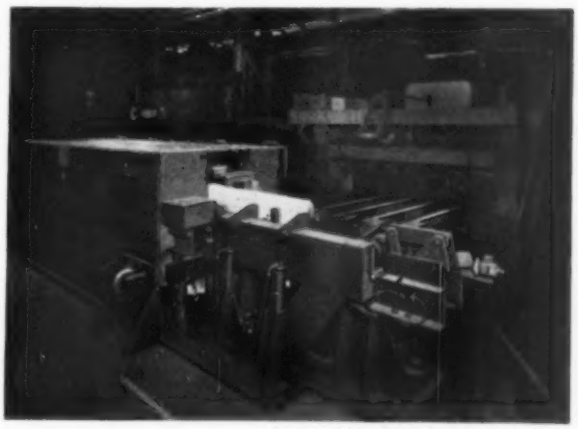


Courtesy of Brayshaw Furnaces, Ltd.

Fig. 43.—Lead bath furnace for continuous blueing of steel strip.

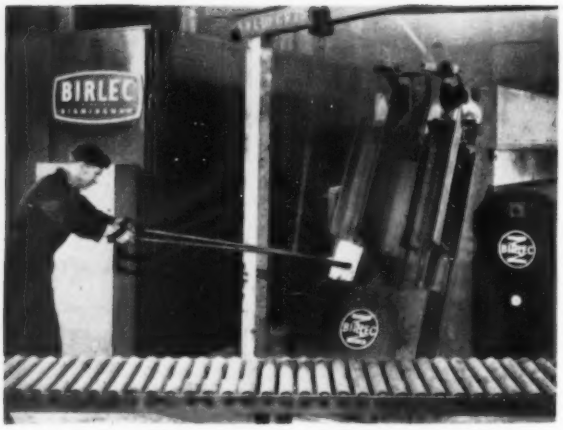
uniformly constant, the temperature throughout the billet must be accurate to within a few degrees of temperature. A pilot induction heating plant for this purpose has been installed at the works of the Weldless Steel Tube Co., Ltd., to heat up to 2 tons of billets per hour. It is believed that this is the first of its kind to operate in the production of ferrous tubes. It should be noted that, for reasons not connected with the plant, the unit works intermittently, and is not in constant use.

The size of billets ranges from 6½ to 9 in. diameter and 3 ft. to 5 ft. 6 in. long. After being heated to 1,300° C., the billets are centred for piercing to form blooms, and subsequently pilgered and finished. The equipment, shown in Fig. 44, is connected to an 11,000 V., 3-phase, 50 c./s. supply through a tapped transformer, which provides adjustment of furnace output. Automatic temperature control enables the billets to be held at the correct temperature until required by the mill. The billets, supported on water cooled rollers, pass progressively through the horizontal heating tunnel comprising



Courtesy of British Geco Engineering Co., Ltd.

Fig. 44.—A pilot induction plant installed by Weldless Steel Tube Co., Ltd., to heat up to 2 tons of steel billets per hour.



Courtesy of Birlec, Ltd.

Fig. 45.—Discharge end of twin-track, dual frequency 1,200 kW. heater for forging billets showing operator removing discharged billet.

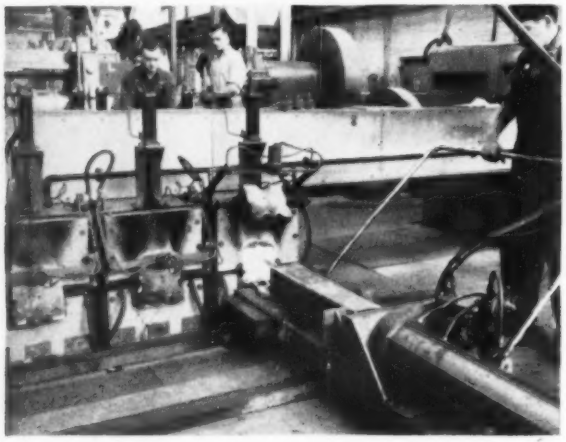
identical water cooled coils. The water connections are on the side opposite to the busbar connections, a recirculating system with automatic control of make-up water being employed with an air-blast cooler. Some of the advantages claimed for this plant include rapid heating up to 1,300° C. in less than 30 minutes, reduced scale formation amounting to approximately 0·5%, ease of handling, absence of fumes and smoke, and the potential for more even heating and closer temperature control.

An important installation of very different design, and comprising a total of four heaters, has recently been commissioned. The largest heaters are rated at 800 and 1,200 kW., and are being used for heating steel billets, up to 6 in. square and 15 in. long, continuously. The billets are moved, end to end, along two parallel tracks by pneumatic pusher mechanism, fresh ingots being fed to the loading end by an indexing chain elevator, and discharged from the offside end down a gravity chute (Fig. 45). Each row of billets passes through two induction heating coil assemblies in succession. The first coil is energised at 50 c./s., since this frequency avoids the need for a converter yet gives a high heating efficiency while the material is in its magnetic condition. On reaching the magnetic change point, therefore, the billets move into the second-stage coils, which are energised at 1,000 c./s. to bring the material rapidly up to final forging temperature. Approximately 50% of the power requirements for the two horizontal billet heaters is thus obtained from the 50-cycle mains supply, the remaining power, and that for the smaller heaters, being furnished by three high-frequency motor alternator sets of 500 kW. each, grouped in a central sub-station and feeding the heaters through co-axial cables. The plant includes an eight-station heater feeding a horizontal forging press.

The flexibility and cleanness associated with induction-heating were largely instrumental in the choice of this method of reheating ingots of special alloys—some of them with high nickel contents—for rolling at temperatures ranging from 800°–1,250° C., at the Crawley works of the Telegraph Construction and Maintenance Co., Ltd. The harmful effects of sulphur on nickel alloys precluded fuel fired furnaces, and the necessity for comparatively

Courtesy of Metalectric Furnaces, Ltd.

Fig. 47.—High frequency generator incorporating a two-position work table and water quench for hardening hammer heads.



Courtesy of Electric Furnace Co., Ltd.

Fig. 46.—Three-coil high frequency induction equipment for heating special alloy billets for rolling.

frequent changes in the rolling programme from one alloy to another requiring a different temperature gave the induction method the edge over a resistance furnace.

To obtain the required output without exceeding the critical rate of heating, three ingots are heated at the same time in three separate inductor coils (Fig. 46), charging being staggered, of course. The cold ingots are charged by a pneumatic pusher which can be positioned in front of any of the three coils. The heated ingot is pushed out on to a live roller table by the incoming cold ingot. Temperature control is effected by a Honeywell indicating controller provided with three Radiomatic heads, one sighted on the ingot in each coil. As soon as the next ingot for rolling reaches temperature, power supply to all three coils is reduced, thus preventing overheating. Because the ingots are tapered, careful grading of the inductor coils is necessary to ensure a satisfactory longitudinal temperature distribution. A

Courtesy of The General Electric Co., Ltd.

Fig. 48.—Showing a container used in conjunction with a high temperature furnace for brazing stainless steel.

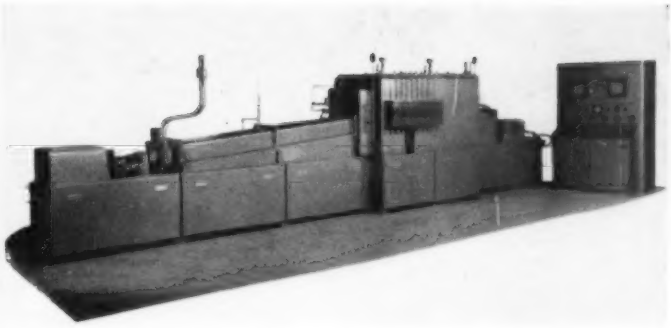
400 kW., 1,050 c./s. motor-alternator is used as the energy source, and an output of 1 ton/hr. is achieved.

A new application for induction heating is that of stress-relieving motor body panels. A floor-mounting cubicle type 20 kW. high frequency generator, complete with work table, has been designed by Metalectric Furnaces, Ltd., for this type of work. The work table is supplied complete with integral recirculating and cooling plant and six work coils so that six stress-relieving operations can be carried out simultaneously in a heating time of 4 seconds. In addition, four air-operated clamps are provided to locate and hold the panel during treatment.

Efco, Ltd., have installed a total of some 1,400 kW. of induction heating equipment for stress-relieving welded joints in large fabrications. The ease with which a heating coil can be mounted over the closely defined locality of the weld greatly simplifies this operation, which can be carried out *in situ*, even on very large structures such as the vessels incorporated in atomic power plant.

A 15 kW. floor-mounting cubicle type H.F. generator, incorporating a two-position work table, with water quench arrangement, is being applied for hardening hammer heads. This unit, shown in Fig. 47, is designed for an output of two hammers per minute.

Another floor-mounting unit is being applied for gear hardening. One of these machines, by Delapena and Son, Ltd., consists essentially of three main components: the H.F. induction heater, a patented intensifier, and the gear hardening machine. The gear to be hardened is mounted on a suitable mandrel and can be indexed to enable the gear to be moved one pitch at a time. The intensifier is connected to the output terminals of the high frequency heater via the output transformer, and is progressed across the face width of the gear; it is located in the valley formed by adjacent teeth and, when in operation, the two flanks of the gear teeth and the root are hardened. The depth of case can readily be adjusted by means of the power supply to the intensifier, or by variations of the traverse speed. The complete hardening process is carried out under water, a large water tank being provided which can be raised or lowered in order to facilitate loading and unloading of the machine. To deal with gears from 2 to 10 diametral pitch, a 15 kW. unit is required.



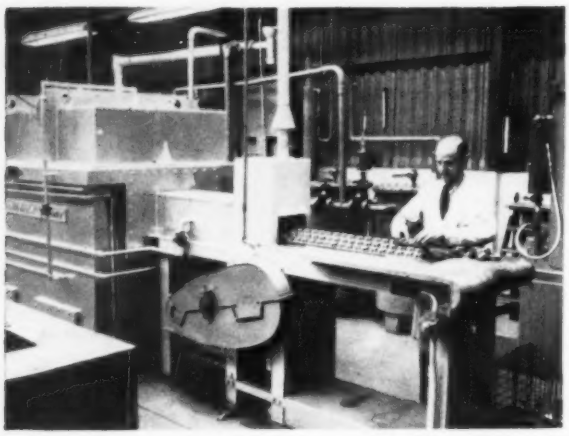
Courtesy of Sintering and Brazing Furnaces, Ltd.

Fig. 49.—Recently developed push pull furnace for sintering.

Sintering and Brazing Furnaces

Brazing together of parts composed of certain materials presents difficulties, this is especially true of stainless steel parts which are required to be brazed either with copper or with the new high-strength high-temperature brazing alloys, when it is desirable to replace fluxes by controlled atmosphere. The G.E.C. technique permits successful brazing in standard high-temperature furnaces. A conventional design of gas atmosphere container is employed, but with the addition of a mild steel inner canister to house the parts to be brazed. An atmosphere of nitrogen is introduced to purge the air from the inner and outer containers followed by a supply of pure dry hydrogen. The hydrogen atmosphere is maintained throughout the heating and cooling cycle, and excellent brazing and bright finished parts are obtained with stainless steels. Fig. 48 shows a container used for high temperature brazing of stainless steel with effective loading dimensions 35 in. diameter and 39 in. high.

The high temperature push-pull furnace developed during the last two years and shown in Fig. 49, has proved very successful for sintering. A push-pull system of boat conveyance is used in which the boats are pushed and pulled through the furnace by hydro-pneumatic action. The effect of this system is to produce a point of "no-load" on a pair of boats in the main heated section of the furnace, and, consequently, a minimum of load on the rest of the boats in that section, thus reducing boat distortion and minimising the risk of jamming in the furnace tunnel. The high temperature zones are heated by tubular element assemblies, spirally wound with molybdenum tape or wire, each being easily removable through the side of the furnace case. A degree of proportional control is obtained in this section by the voltage of the secondary feed of the transformers supplying the elements being automatically switched to a lower tapping upon reaching the desired zone temperature. The first zone is heated with nickel-chromium elements, the power being supplied by low voltage secondary oil or air-cooled transformers and takes the form of a preheat section for



Courtesy of Metalectric Furnaces, Ltd.

Fig. 50.—The charging end of a continuous mesh belt conveyor bright copper brazing furnace.

bringing the incoming work up to 1,050° C. All zones in the main heated sections of the furnace operate at temperatures up to 1,350° C. Two sizes of this design of furnace are at present in production for outputs of 60 and 150 lb./hr., respectively. They are supplied with fully automatic temperature control equipment with consumption of hydrogen or cracked ammonia at 80–120 cu. ft./hr.

A recent installation, Fig. 50, is a continuous mesh belt conveyor bright copper brazing furnace, rated at 35 kW. and having a usable belt width of 8 in., opening height 6 in., and length of heating chamber 4 ft. 6 in. It is designed for operating at temperatures up to 1,150° C. The furnace is of gas-tight construction for use with a controlled atmosphere, and a feature is the provision of a lift-off roof for the heating chamber, to permit easy access for maintenance and inspection. A chrome-ore seal ensures gas-tightness of the roof in its lowered position.

A G.W.B. bell furnace installation for brazing stainless steel components has two loading bases and one dummy base on which the furnace heating bell can be placed if necessary. The usable dimensions of each base are 2 ft. 6 in. diameter × 3 ft. high, and each is provided with a gas-tight charge retort containing the protective atmosphere derived from a cracked ammonia plant and a de-ammoniator. To provide an effective seal against atmosphere leakage at the base of the retort, a low melting point metal in an annular trough is used.

New Hot Rolling Mill for Stainless Steel at Samuel Fox

WORK has started on a £1m. scheme to modernise and expand the stainless and alloy steel sheet rolling plant at Samuel Fox & Co., Ltd., Stocksbridge, a subsidiary of The United Steel Cos., Ltd. The development is being carried out in two stages: (1) the widening of the existing cold rolling mill to produce sheets up to 72 in. wide by the end of this summer; and (2) the installation of an entirely new hot rolling mill for sheets and light plates up to 72 in. wide, which will come into operation by the summer of 1960.

When the scheme is completed, Samuel Fox will be able to supply stainless and alloy steel sheets up to 30 ft. long, 6 ft. wide and $\frac{3}{4}$ in. thick, with a maximum weight of about 3,000 lb. In the initial stages, annual output of the new plant will be about 11,000 tons, of which slightly more than half will be plates, the balance being either hot or cold rolled sheets.

The new hot mill is being largely engineered at the Stocksbridge works, and will incorporate a number of novel features. As a two-high mill with an 83 in. barrel length, it will be capable of rolling 5 in. thick slabs into plates and sheets in single thicknesses from $\frac{3}{4}$ in. to $\frac{1}{8}$ in. thick. The mill can also be set up as a four-high unit, with work rolls of about 15 in. diameter, and a second set of driving pinions will then be brought into use. In that form, and after doubling, hot rolled sheets from $\frac{1}{8}$ in. to 0·050 in. thick will be produced, either for direct sale or for subsequent cold rolling.

A new walking beam re-heating furnace is being installed to serve the hot mill. Equipped with fully automatic control, the withdrawal gear will enable either a slab or semi-rolled plate to be handled by push-button. The discharge table of the furnace will be fitted with a manipulating table for turning and aligning the plates or sheets before delivery to the mill. Special breast rollers will carry the sheets fully into the pass line of the small work rolls.

Widening of the existing Sack cold rolling mill will enable it to handle suitably thin sheet from the hot mill in order to produce cold rolled sheets up to 72 in. wide and down to 0·022 in. thick. An additional feature of the modernised cold mill will be its ability to roll heavy sheets and light plates, thus giving a much improved surface finish.

Computer Controlled Gas Cutting Machines

SWAN, HUNTER, & WIGHAM RICHARDSON, LTD., of Wallsend-on-Tyne, and Vickers-Armstrongs (Shipbuilders), Ltd., of Barrow-in-Furness, will be the first British shipyards to install the computer controlled profile cutting machine, developed by British Oxygen Gases, Ltd., in conjunction with Ferranti, Ltd. Both of these companies have recently ordered prototype machines for installation in their yards next year. Computer controlled profiling, can be regarded as a major step towards the introduction of automation in shipbuilding. The system is also designed to achieve other important savings in the cost of production.

Directory for Technical Publicists

IN view of the growing number and professional importance of technical writers, translators, abstracters, specialist copywriters, etc., in British industry, a new annual register, the first in Britain, of these and allied professions will be published shortly. The publication will list essential personal and professional data. Interested readers are invited to apply as early as possible for forms entitling them to free listing in "The Annuary of British Technical Writers and Translators." It is hoped that the collation of a national list will stimulate the development of a professional association. Enquiries regarding the Annuary should be sent to: The Editor, Annuary Section, Euro-Teknika, 12 St. George's Road, London, N.W.11. A stamped, self-addressed envelope must be enclosed.

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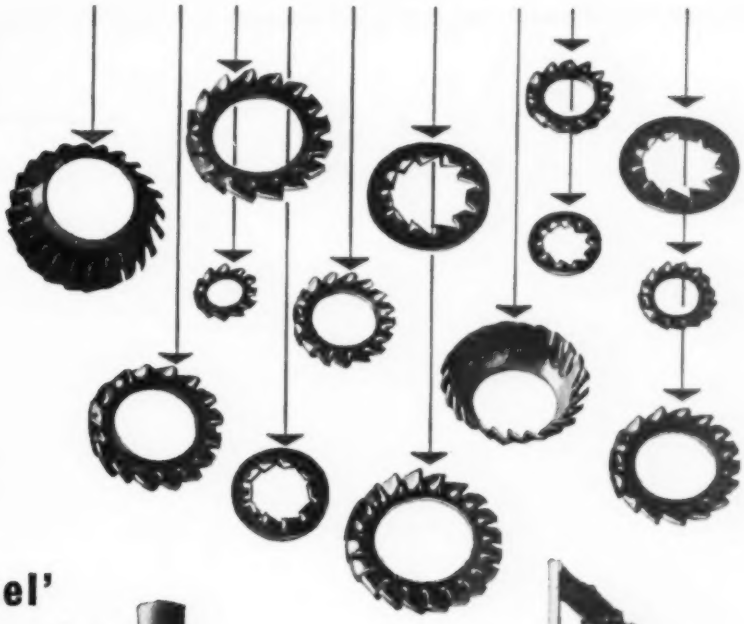

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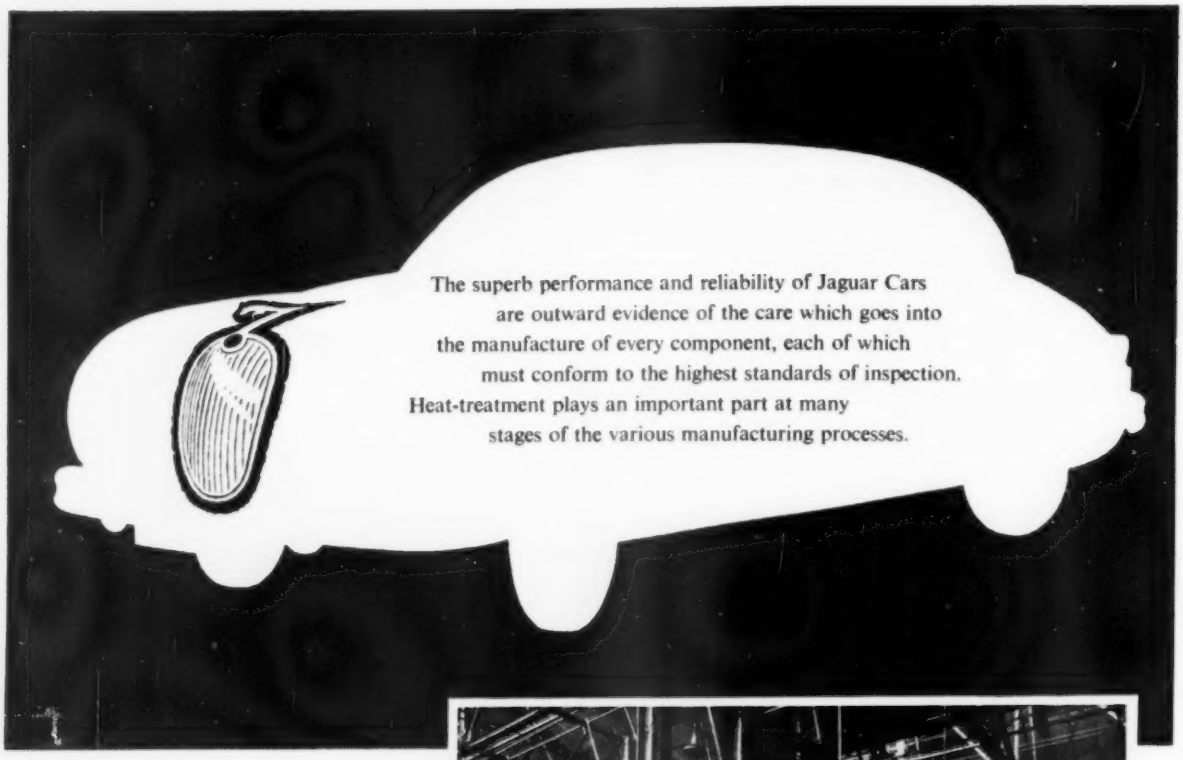
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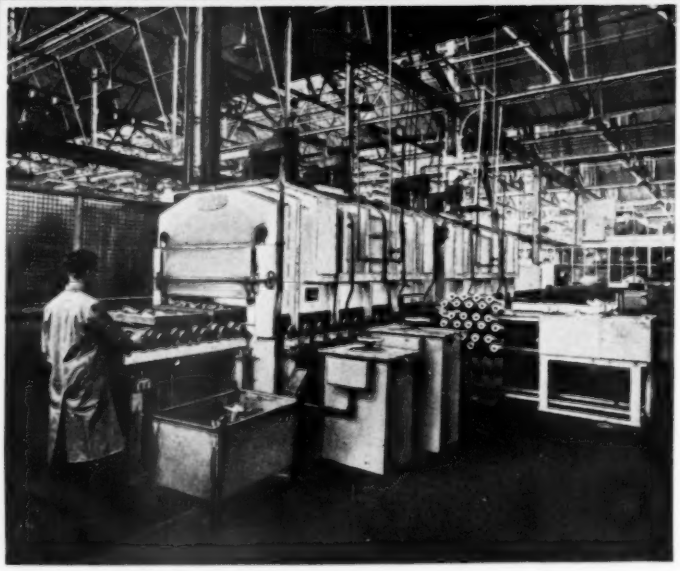

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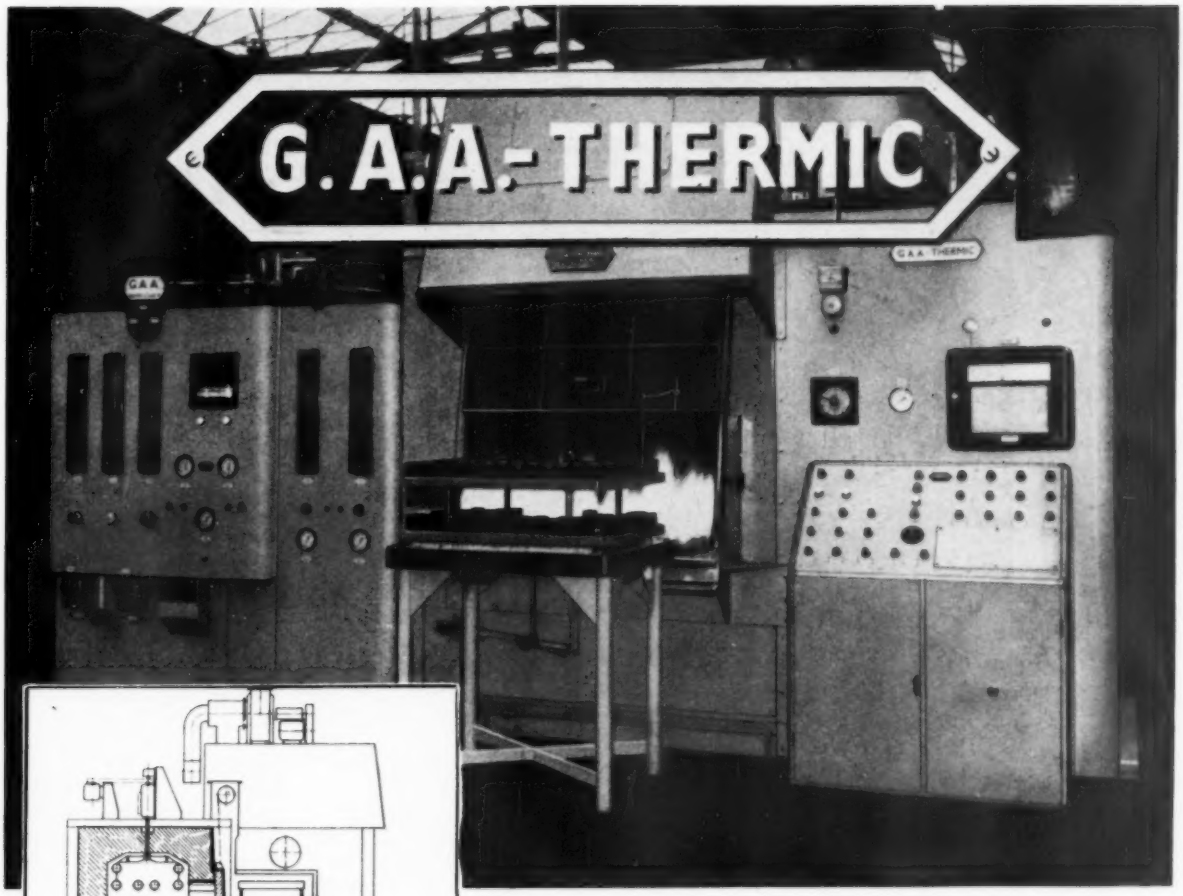

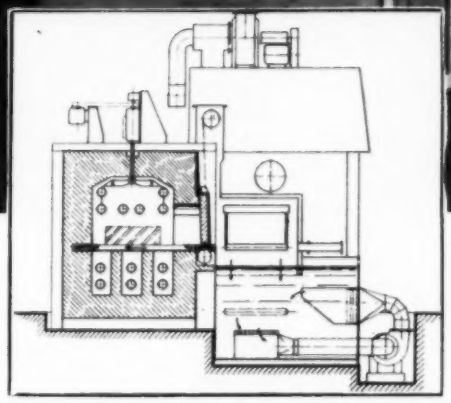

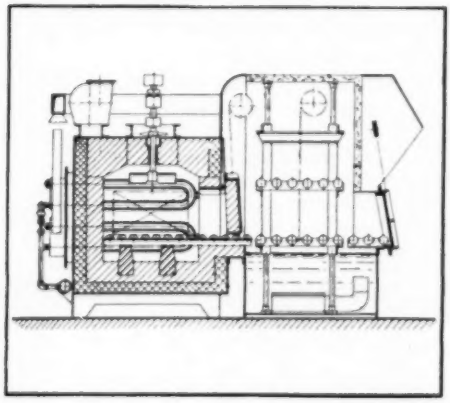

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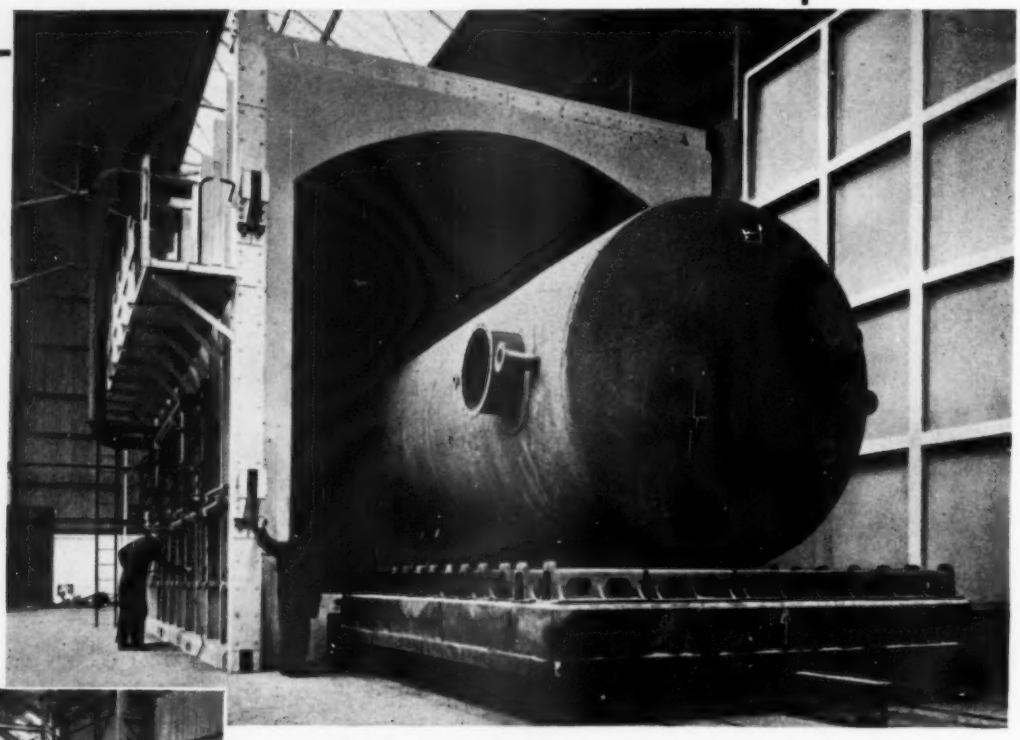
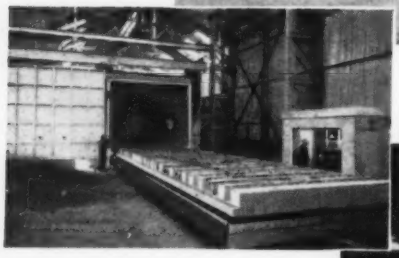
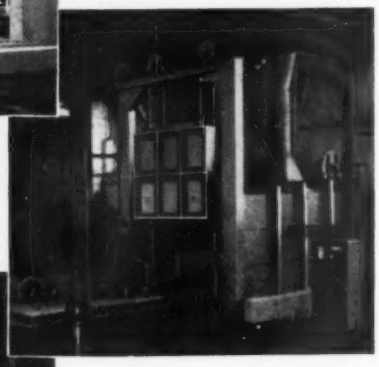


ENGLAND: Stress-Relieving Furnace internal dimensions 16' 6" wide × 16' 6" high to crown by 35' 0" long, in the Works of Newton Chambers & Co. Ltd., Thorncliffe, Nr. Sheffield.



AUSTRALIA: Furnace 14' 0" wide, 11' 0" high, 43' 0" long.



PORTUGAL: Furnace 8' 0" wide, 5' 7" high to crown × 11' 3" long inside.

SOUTH AFRICA: Furnace 14' 0" wide, 14' 4" high, 43' 0" long, Babcock & Wilcox of Africa (Pty.) Ltd.

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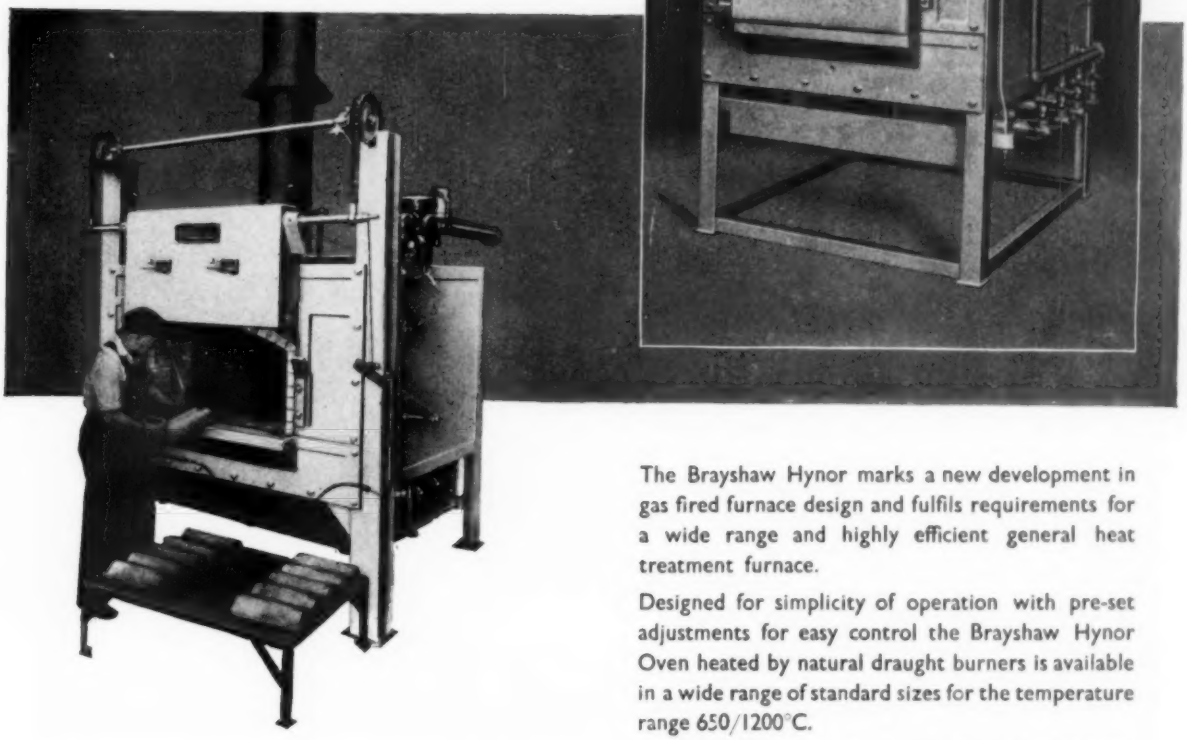

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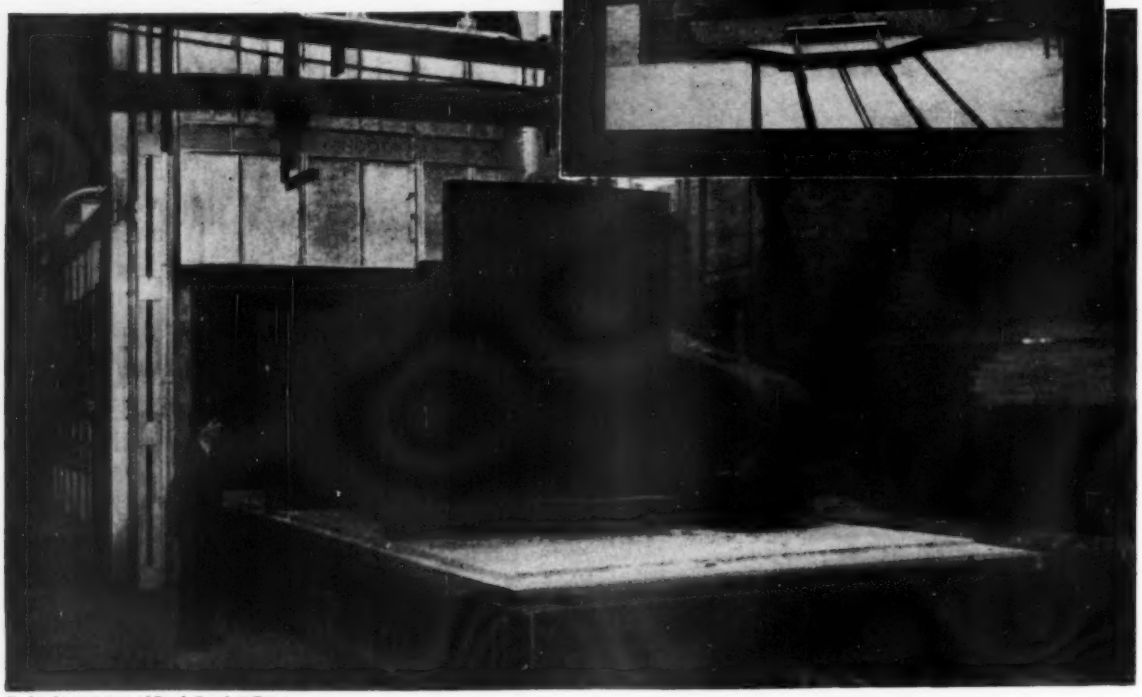

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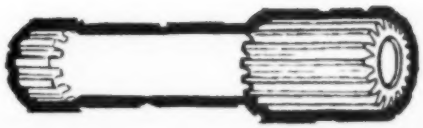

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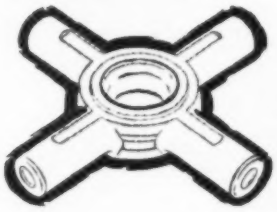

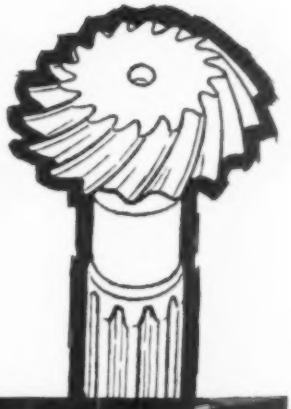

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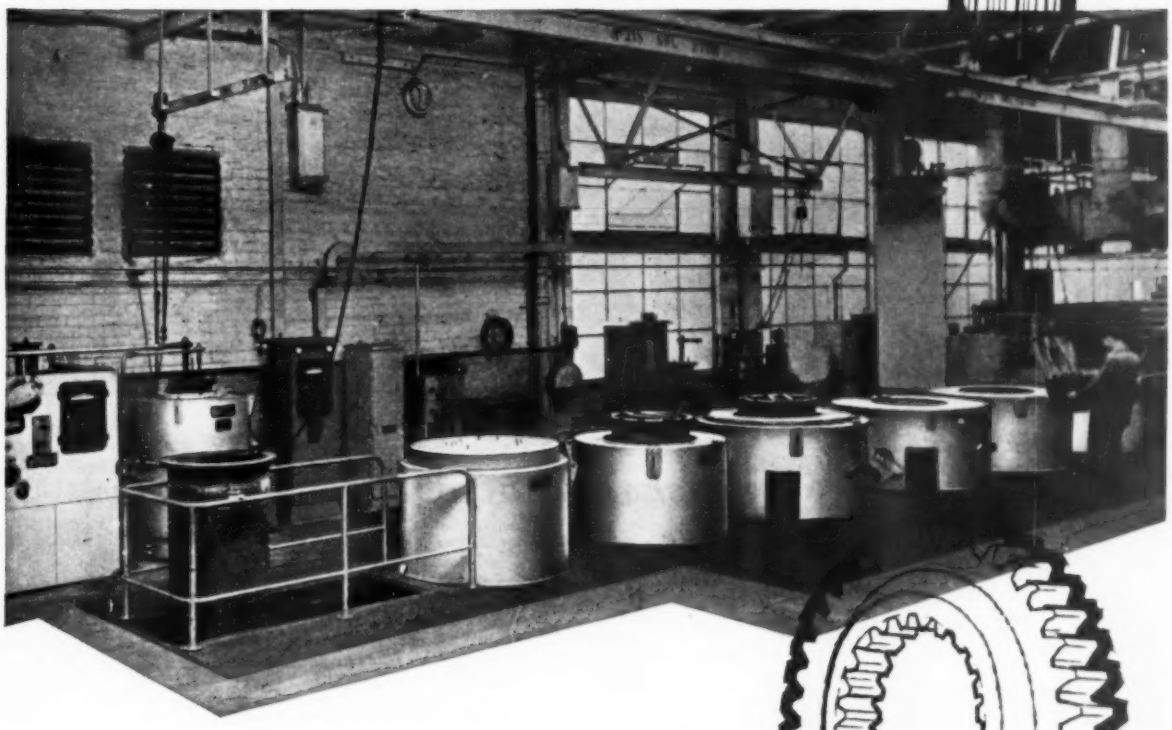

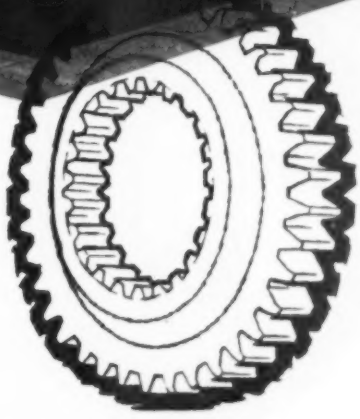

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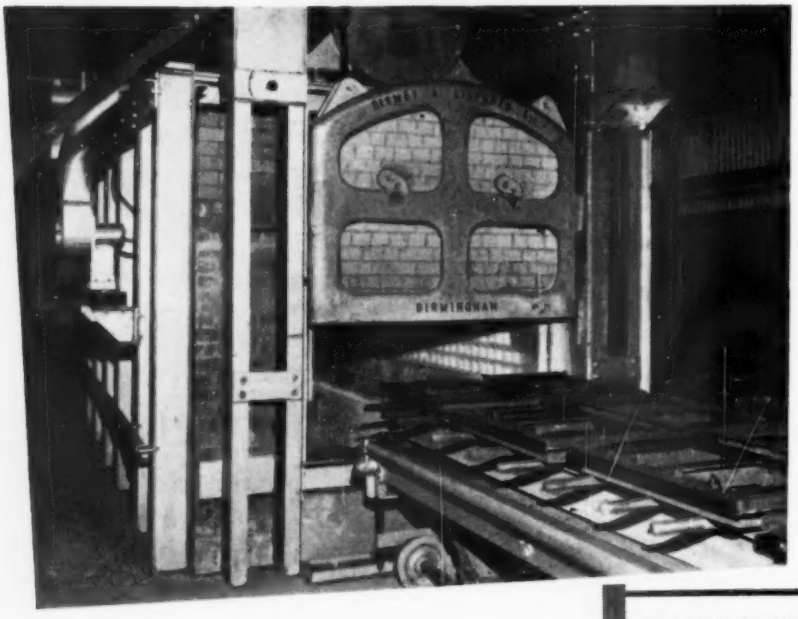

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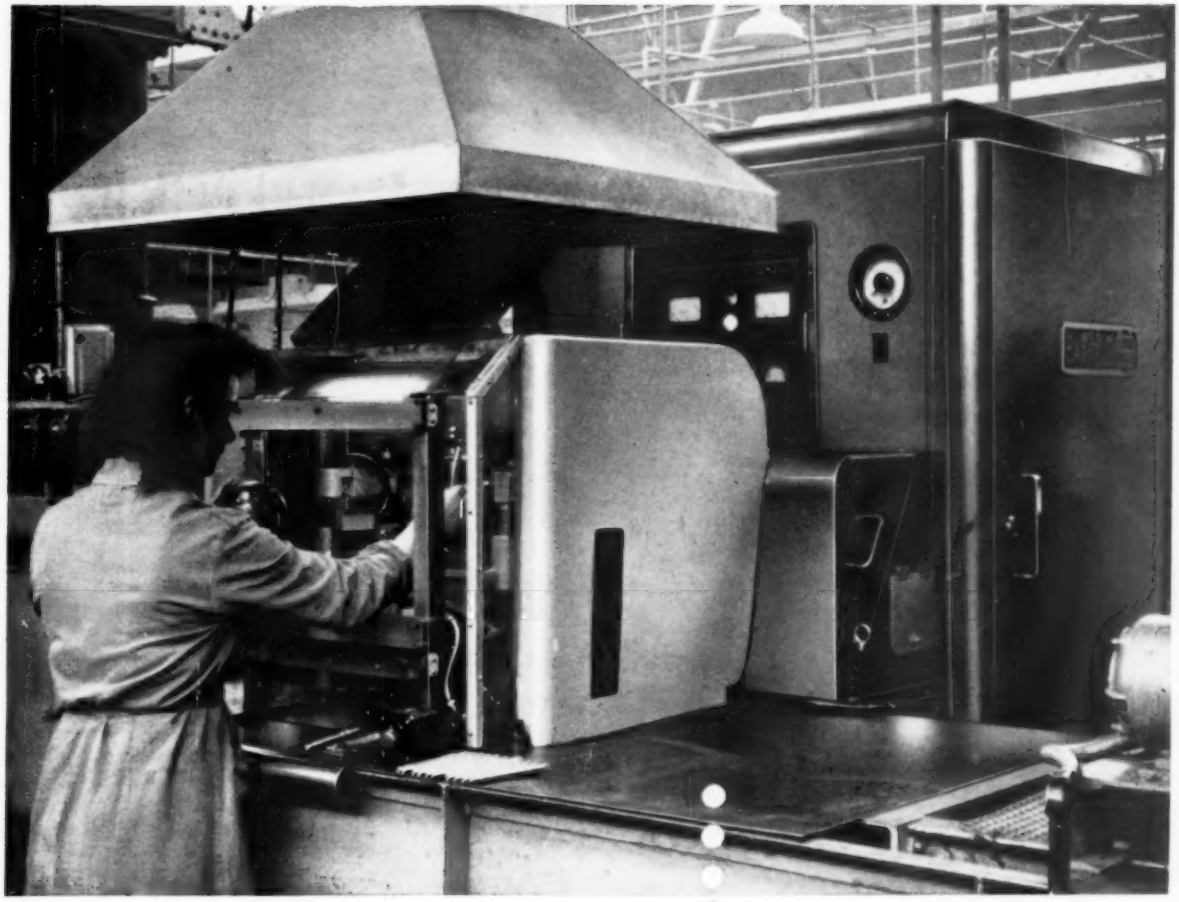

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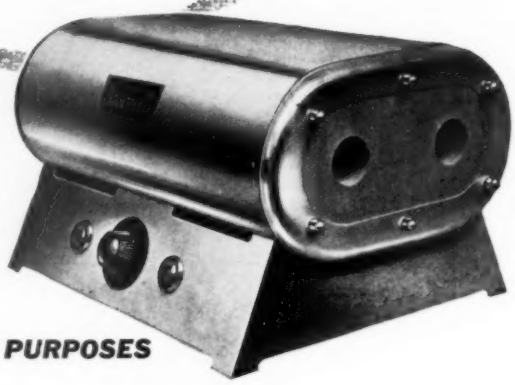

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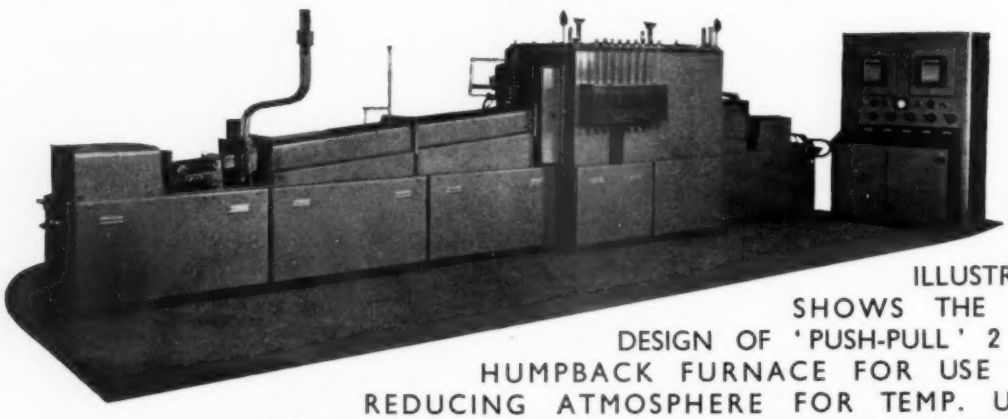

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Observations on the Process of Nickel Deposition by Thermal Decomposition of Nickel Carbonyl at Low Pressures

By L. W. Owen, B.Sc.

Atomic Weapons Research Establishment, Aldermaston

An account is given of observations made and experimental determinations carried out during the development of a method for the deposition of nickel by thermal decomposition of nickel carbonyl at low pressures. Details are given of the variables controlling the process and the properties of the coatings obtained, such as appearance, micro-structure, micro-hardness, ductility, etc. The adhesion and porosity of the coatings on various metallic bases are assessed and also such factors as the control of thickness applied and the distribution on various shapes. The role of variables such as temperature, pressure, rate of flow and composition of vapour are discussed and an attempt is made to relate these factors with each other and the properties of the coating.

(*Continued from page 233 of the May issue*)

Dilution of Nickel Carbonyl Vapour with Other Gases

Owing to the fact that carbon monoxide is liberated as a result of decomposition of the carbonyl, it might be said that there is always a diluent gas present during plating. The fact that there are four volumes of carbon monoxide liberated for every unit volume of nickel carbonyl decomposed means that dilution of the nickel carbonyl in the region of the plating surface must be considerable. During the first instant of plating, deposition does occur from undiluted vapour, however. The properties of the film thus formed initially might differ considerably from one formed in the presence of carbon monoxide, and it might be instructive to examine this point a little further. Without special means to increase the thickness of the film, assessment would be a difficult matter. By repeating the exposure to fresh carbonyl vapour a number of times in succession, a thicker coating could be built up which could be assessed by normal methods. An approach to conditions where plating would occur continuously from comparatively undiluted vapour should also be obtained by employing high vapour velocities in an upward direction of flow, where the carbon monoxide liberated would be instantaneously swept away from the specimen and little premixing could occur.

Apart from plating under exceptional conditions, the vapour entering the bell jar would become diluted as it approached the plating specimen, the extent of dilution depending particularly on whether the flow was downward or upward (see Section V.3.). The general effects of adding carbon monoxide to the vapour entering the bell jar must, therefore, be to cause further dilution and to intensify any other effects due to its presence. Effects should be greatest where the concentration of carbon monoxide liberated by the decomposition of vapour is normally low but there is considerable heat radiated from the specimen. Near the specimen, where the concentration of carbon monoxide is normally high, or remote from it, where heating would only be slight, the effect of added carbon monoxide would be least. Reduced tendency to black powder formation may be directly attributed to added carbon monoxide exerting a stabilising effect on the vapour in regions where black powder tends to form (see Section V.2.). The use of carbon monoxide as diluent gas does not appear to result in an increase of carbon in the deposit at 200° C. Other effects somewhat inconclusively associated with the use of carbon monoxide as diluent gas are less readily explained, e.g. improved appearance; better ductility under some circumstances; lesser tendency for fissure formation when plating at low specimen temperatures; and development of a columnar type of microstructure with larger grains. It is possible that the stabilising action of added carbon monoxide having the effect of reducing black powder formation will, under more favourable conditions, effect a reduction in the extent from the specimen walls at which decomposition is occurring, and thereby shorten the path traversed by nickel liberated in the gas phase and reduce the tendency for nickel to be deposited as coalesced particles (see Section V.2.). The effect, however, may be too small, since near the specimen walls the concentration of carbon monoxide liberated would already be high and conditions might not therefore be greatly affected by a small addition. Clearly, this subject is one which should repay study in some detail.

One general effect of diluting the nickel carbonyl vapour with other gases is, of course, to increase the mean linear velocity of the vapour through the bell jar, the mass velocity of vapour and pressure remaining unaffected. The reduction in efficiency is thus attributed to increased linear velocity (see Section V.4.). The effect of dilution alone (i.e. with no change in linear velocity) with inert gases such as argon and nitrogen would be expected to be an increase in efficiency rather than a reduction. The greater tendency towards black powder formation observed could be due to increased linear velocity, but dilution of the carbon monoxide present might also be a contributary factor. Apart from any stabilising action carbon monoxide may have on vapour decomposition by mass action effect, the relatively low thermal conductivity of carbon monoxide may also play a part, and the substitution of another gas of higher

thermal conductivity might be expected to result in more black powder formation. The effect of employing as a diluent gas hydrogen, which has a very high thermal conductivity, seems to bear out this point, since the tendency to blackening is most marked and the appearance of coatings seem to be affected, being darker and rougher.

Nickel in bulk is not very reactive towards oxygen at normal plating temperatures, so that the great reactivity here must be due to the "nascent" condition of the nickel liberated and the extremely fine state of division. It seems probable that some nickel is deposited as oxide and some is oxidised after deposition, although the reactivity after deposition seems to diminish rapidly. If all traces of nickel carbonyl vapour are pumped out of the plating vessel and air admitted with the object still at plating temperature, no visible oxidation occurs; if a trace of nickel carbonyl vapour is introduced, however, interference colours will immediately appear. It is possible to continue deposition with the plate exhibiting interference colours. Decomposition efficiency does not seem to be very much changed, although it is not known how much oxide the deposit contained. Presumably conditions could be reached where the deposit was more or less pure nickel oxide.

Investigation of the effects of the variables on the properties of the coating is undoubtedly simplified by the fact that small amounts of air unavoidably present in the system from its leak rate are insufficient to affect the properties of the coating. Whether this is due to the tolerance of nickel for small amounts of oxygen or the reducing action of carbon monoxide present in the system is not certain. Obviously the gas mixture extracted from the bell jar should be tested for carbon dioxide in the first instance.

V.6. Efficiency of Deposition

Fig. 3 shows clearly the variation of the efficiency of deposition with specimen temperature, the rapid rise between 100° and 200° C., and the decline in efficiency with increase in temperature above 220–230° C. At higher rates of flow and linear velocities (lower pressures), the form of the curve would probably be similar, although somewhat more rounded, but the point of maximum efficiency would be at a lower temperature. The decline in efficiency with increase in temperature above a certain maximum corresponds roughly to the onset of black powder formation, but it has not been established whether, or how far, the loss in efficiency is entirely accounted for in terms of the black powder formed and increased plating on thermocouple points, insulators, etc.

The decrease in efficiency with increased mass throughput of vapour at constant pressure is shown graphically in Fig. 4. The efficiency fell steeply at first but diminished more slowly at higher flow rates, becoming almost linear. Deposition times employed were one hour for each determination; results employing shorter times of plating were considered likely to be affected by unsteady conditions prevailing at the commencement of plating. The loss in efficiency with increased vapour flow rate must be due to the accompanying increase in mean linear velocity of the vapour and not to the pressure, since the latter was kept constant. Had the linear velocity been kept constant, any variation of efficiency with mass velocity would then be due to pressure variation, but would probably be small.

Plating efficiency was decreased by mixing the vapour with other gases. Again, this loss in efficiency is probably due entirely to the accompanying increase in linear velocity of vapour. At constant linear velocity, dilution with other gases except carbon monoxide might have the effect of increasing efficiency.

V.7. Distribution of Coating Thickness

In common with most methods of deposition, there is a marked tendency for the more exposed surfaces to receive more than average coating thickness and recessed areas to receive less. Unlike electrodeposition processes, distribution of the coating on the object to be plated does not depend on accessibility of the surface to current, nor as in vacuum evaporation to accessibility to streamline flow. The most important factors preventing even distribution on surfaces accessible to carbonyl vapours are probably:

(*a*) lack of uniformity in composition of the atmosphere surrounding the specimen in the bell jar; and

(*b*) restricted movement of gases in recessed areas, particularly blind bores.

As regards (*a*), the plating atmosphere clearly becomes impoverished in nickel carbonyl as it flows over the specimen, and thus the coating will be thinnest where it is farthest from the oncoming vapour; other factors also contributing to the lack of uniformity will be apparent from what has been said in Section V.3. If the conditions are such that the efficiency of decomposition is not very high, the uniformity of composition of the nickel carbonyl-carbon monoxide mixture will be better maintained, however, and hence the coating thickness will be more uniform. Lowering the specimen temperature would result in low efficiency, and hence more uniform plates, but this is clearly undesirable for reasons already stated; the alternatives could be to employ a high linear velocity of vapour by reducing the pressure or mixing it with carbon monoxide. The feasibility of employing mechanical aids to mixing has not been investigated although it has been the subject of a U.S. patent[10]. Providing that excessive black powder formation could be avoided, there would seem to be a prospect of achieving some improvements by this means. An extremely effective method of promoting uniformity in coating thickness is to reverse the direction of flow of vapour during plating; this can be done without interrupting plating. Alternatively, the specimen can be rotated or inverted.

As regards (*b*), the reduction in rate of deposition in recessed areas depends upon the extent to which gas movement is restricted and the greater reliance upon diffusion as the means of transport of nickel carbonyl to the surface inside a recess. The thermal expansion of the gases present and the four-fold increase in volume resulting from decomposition of the carbonyl cause movement away from the recess, and thus oppose diffusion into it. Directing vapour into the recess at a relatively high velocity has been found an effective method of increasing the uniformity of thickness of coating.

V.8. Adhesion and Porosity of Coating

The problem of obtaining adherent deposits by this process is presumably, in common with other coating processes, one of ensuring a chemically clean surface at the commencement of deposition. Most of the commonly used metals can be effectively cleaned by appropriate degreasing and acid pickling treatments, and the prob-

lem therefore is more one of preventing the surface becoming soiled or re-oxidised. In a dry plating process such as that under investigation here, the object has to be dried before it can be plated, and the opportunities for soiling or re-oxidation are greater than in a wet plating process such as electrodeposition, where direct transfer to the plating tank immediately follows pickling and rinsing. Moreover, the object has not only to be dried but also heated up to plating temperature. Admittedly this is done in a good vacuum, but oxidation of the more reactive metals can nevertheless occur. When the object to be plated is placed in the vacuum, and during the process of heating it to plating temperature, adsorbed and occluded gases are released. Presumably outgassing could be sufficiently vigorous to interfere with the process of deposition, resulting in poor quality porous non-adherent deposits, but there has been no evidence of this occurring, perhaps because during the heating of the object to plating temperature the bulk of the gases have been removed. Doubtless, evolution of occluded gases continues to some extent when plating temperatures have been reached; in fact, complete outgassing would require times which would be impracticable for a plating process, and it is therefore a question of deciding when outgassing has for practical purposes been reduced to a level where its effects can be ignored. No actual experiments have been carried out, but experience would suggest that normally this stage has been reached by the time the object has achieved plating temperature. Lengthy periods of outgassing certainly do not necessarily achieve adherent, non-porous deposits, and on the contrary adherent deposits have been obtained with no outgassing other than that during the heating-up period. However, to allow a margin of safety it is suggested that a period of outgassing of half an hour at 300–400° C. achieves all that is necessary in this connection. High adhesion obtained on copper is, however, not considered to be due to outgassing the metal, but to the removal of oxide or other films at the surface which would otherwise act as a barrier to adhesion. The tarnish film on copper can be visibly removed by heating in vacuum for a few minutes only at about 700° C. Although it is preferable, it is not necessary, however, to employ such a high temperature in order to achieve high adhesion, provided a longer period of outgassing is given, e.g. one hour at 400–500° C. has achieved the same result. How the surface film is removed is not certain, since the film present is likely to be Cu_2O, which is not appreciably dissociated or evaporated at moderate temperatures (CuO would be much more readily dissociated). Presumably the film diffuses into the parent metal, or it may possibly be reduced by carbon monoxide coming from the interior. As heat treatment has led to high adhesion being obtained in the case of one metal only out of seven, there appears to be no point in recommending it as general procedure. Heat treatment after deposition, however, has led to strongly adherent coatings on mild steel and copper, and there seems a reasonable chance that similar results will be obtained on other metals when the right temperature and time of treatment have been found. It seems that films, probably oxide, on the surface which were sufficiently thick to prevent adhesion of the coating during deposition can be broken down subsequently at higher temperatures. Intermetallic diffusion probably occurs through local discontinuities in the film, which leads to general disruption and dispersal. Nickel coatings of moderate adhesion to aluminium obtained without post deposition heat treatment suggest that diffusion through the oxide film has occurred at plating temperatures. Evidence of the presence of a diffusion layer was obtained on examination. Post-deposition heat treatment is therefore considered to be a more generally effective method of securing adhesion than pre-deposition heat treatment, and it is hoped that further examples of adherent coatings on other metals will be obtained. Limitations obviously arise, however, where extensive brittle intermetallic compounds are found in the diffusion layer, or where there is great disparity between the coefficients of thermal expansion.

Breakdown of oxide films leading to a high degree of adhesion might be obtained by evaporation of surface layers of the metal or sputtering with positive ions. Few metals have adequate rates of evaporation below their melting points, however. Improved adhesion on brass obtained by evaporation of zinc from the surface might have been due to the conversion of the surface to one rich in copper rather than mechanical disruption of any film present. Positive ion bombardment has shown itself to be a useful technique in removing films from the surface of metals, but there is usually considerable heating of the object during treatment, and there would be the risk of re-oxidation in cooling down to plating temperatures. The necessary equipment incorporated in the plating chamber could render the whole somewhat cumbersome.

It may be of interest to record that porosity of the coating, as indicated by chemical tests, is of the order comparable with electrodeposited nickel. Since porosity in electrodeposited coatings is attributed in part to the presence on the substrate surface of non-conducting particles, it might be anticipated that carbonyl nickel coatings would be less porous, since lack of electrical conductivity would offer no obstacle to deposition. Furthermore, there is no possibility as in electrodeposition of bubble formation giving rise to pits and pores in the coating. As carbonyl nickel coatings have shown evidence of greater reactivity towards chemical attack than electrodeposited coatings, they are probably more easily corroded by the reagents employed for the test, and the true porosity may actually be lower. Porosity in carbonyl nickel coatings could arise from imperfections in the surface of the object plated (a suggested cause in electrodeposited coatings), e.g. minute holes and crevasses which do not plate completely down to the bottom. Imperfections in the coating, such as gaps and fissures associated with nodular and dendritic types of growth, could also lead to porosity. The extent of the gaps and fissures downward into the coating, however, would rarely be so deep as to expose the underlying metal, although this might subsequently happen as a result of reagent attack.

V.9. Properties of the Coating

Carbonyl nickel coatings produced under favourable conditions compare well with electrodeposited nickel coatings (Watts bath), and it would not always be easy to distinguish between them visually, especially at low thickness. Below about $0{\cdot}5 \times 10^{-3}$ in. carbonyl coatings have a polished silvery appearance, but generally become matt above this thickness. When matt, the colour of carbonyl nickel coatings would generally be of a darker shade than electrodeposited nickel, i.e. greyish, and the texture somewhat more matt. Carbonyl coatings produced at higher plating temperatures would appear whiter than electrodeposited coatings, whilst in the

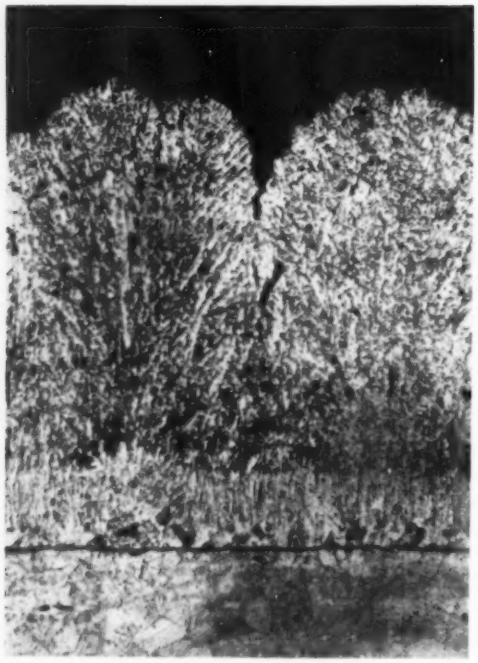

Fig. 33.—Nodular structure. Etched 5% nital + 10% hydrogen peroxide. × 270

presence of a certain proportion of oxygen they would be brighter and smoother above about $0{\cdot}5 \times 10^{-3}$ in. in thickness. Light burnishing of both carbonyl and electrodeposited matt coatings would render them similar in appearance.

The presence of nodules on the coating has been fairly generally observed, especially on the thicker coatings. Nodules visible to the naked eye are few, but under magnification they are seen far more extensively. The larger type of nodule is often irregular in shape and could easily be due to particles such as grit, small fragments of metal, and organic material such as fluff, dust, hair, etc., loosely attached to the surface of the specimen. Direct evidence of this was obtained in at least one instance (Fig. 34), when a filament type of growth was obtained as a result of the presence of a small fibre of textile material on the surface of the specimen at the commencement of plating. The vegetable fibre had probably become charred at outgassing temperatures, and nickel deposition took place on the carbonaceous remains. The two filaments seen were originally part of one continuous filament, the middle portion having become broken away. It will also be observed that the appearance of the coating surrounding the thread differs from that of the remainder.

That the presence of foreign particles on the surface of the specimen can produce an irregular type of growth has been demonstrated in one example (Fig. 34), and it is not difficult to visualise that numerous particles, much smaller in size and not readily visible to the naked eye, could conceivably lead to the development of a nodular type of coating. The micro-section in Fig. 22 suggests how roughness of the base metal could give rise to a nodular appearance. However, it would seem doubtful whether the closely knit widespread nodularity seen in Fig. 11 could arise from these causes, and it is much more probable that some factor connected with the plating process itself is responsible. Oxygen would not normally be present in sufficient amounts to cause nodularity (Section V.5.). The formation and coalescence of nickel particles in the vapour phase prior to deposition has been discussed in Section V.2., and it is suggested that nodularity might arise from this cause. Whether such particles would be of sufficient size to initiate nodular growth is difficult to assess: according to Cuckow,[11] however, particle size of black nickel powder formed by carbonyl decomposition is extremely small. In some coatings the presence of a continuous system of nodules at magnifications of 200–300 diameters is not apparent, as, for instance in Fig. 13, and it is doubtful in Fig. 14. The surface shown in Fig. 15 was sufficiently smooth to present a polished appearance to the naked eye. In the example in Fig. 11 it will be observed that the coarse nodules appear composed of much smaller nodules.

The photomicrographs illustrating the types of structure, i.e. Figs. 16–23, 32 and 33, have been selected on account of their comparative lack of ambiguity. The structures exhibited were usually less clearly defined, and often more than one type of structure was present in the area under examination. There was, however, usually no difficulty in recognising the type of structure present, providing that the preparation and etching had been carried out with due care. It was, however, sometimes difficult to distinguish between fibrous and dendritic types.

The broad columnar type of structure characteristic of electrodeposited nickel from a Watts type of bath has not been observed frequently in carbonyl nickel coatings; an acicular type of columnar structure is more common. Coatings with a broader type of columnar structure are, however, more frequently obtained using carbon monoxide as diluent gas. Dendritic types of structure exhibiting numerous fissures are commonly shown by coatings produced at low temperatures and also possibly high pressures and low linear velocities. Coatings with such a structure are usually very brittle.

A further characteristic apparent in nickel carbonyl coatings is the frequency with which the type of structure can vary under similar conditions of plating. It is not uncommon to observe more than one type of structure in the same micro-section.

The effect of heat treatment on carbonyl nickel coatings is shown in Figs. 24–28. It may be of interest to note that the electrodeposited nickel backing has retained its columnar form, whilst the carbonyl nickel coating has recrystallised. At 600° C. the carbonyl nickel coating has undergone a slight grain growth (Fig. 25), and the electrodeposited nickel backing has recrystallised and appears similar to the carbonyl nickel.

A distinct analogy is to be observed between electrodeposited bright nickel and nickel deposited from carbonyl vapour containing a certain proportion of oxygen. The organic addition agent added to nickel plating solutions has a smoothing action and enhances brightness of the coating, these effects being accompanied by a considerable increase in hardness, reduction of ductility and grain size, and the development of a banded type of structure. All these effects can be produced in nickel carbonyl deposits by adding oxygen to the nickel carbonyl vapour.

Extremely ductile coatings have been obtained, but it is not yet possible to define the conditions under which they may be produced reliably. Evidence so far suggests

that the coatings can be produced at conditions not very far different from those given in Section III. A temperature of 220° C., a pressure of less than 2 mm. and a rate of flow of vapour equivalent to 1 g. per hour appear to be favourable, especially with an addition of several litres per hour of carbon monoxide. A high order of ductility, however, is not often found among coatings which have a matt texture, but nevertheless, highly ductile matt coatings have been obtained. Samples of coating from the same specimen showed a variation of the order of 10 to 1 in ductility between the bright and the matt parts. A matt texture normally develops when the thickness of the coating exceeds $0{\cdot}5 \times 10^{-3}$ in. and consequently, since most coatings are thicker than this, extreme ductility is not common; usually where it is found the coating has for some reason remained bright. A search for conditions leading to reliable production of extremely ductile coatings should therefore be aimed at finding the factors responsible for the development of matt texture. Plating at the conditions mentioned above appears to favour retention of brightness, sometimes up to a thickness of 1 to $1{\cdot}5 \times 10^{-3}$ in., but cannot be relied upon by any means to do so in a particular case, and other factors not understood therefore appear to be involved. The maintenance of surface temperature may, for example, be very important, because if the temperature drops even momentarily the change to matt may be initiated. It has been shown that deliberate lowering of the specimen temperature during the bright stage of plating can initiate the change to matt. The fissured dendritic type of growth associated with low temperature plating may also be initiated, and may be the real factor responsible for the brittleness. Measurement of surface temperature is at present only approximate and rapid changes could occur unobserved. More precise control of surface temperature may, therefore, be revealing and worth the effort of investigation. Pre-heating of the vapour appears to be of some assistance in maintaining brightness of coating; perhaps by preventing or minimising local reductions in temperature; results are by no means conclusive, however.

VI. CONCLUSIONS AND RECOMMENDATIONS

Coatings of good appearance and properties have been obtained readily by this method of deposition at a high efficiency of vapour decomposition. Control of temperature was the most important factor as regards the soundness of the coating, whilst accurate control of vapour flow was important in applying a desired weight of coating.

A high degree of adhesion of the coating is necessary on certain metals, vacuum outgassing and post-deposition heat treatment being beneficial for achieving this. Except in the thinnest coatings, porosity was generally of a low order. Distribution of coating thickness over solid objects and into recesses was generally good, and could be improved by reversing the direction of vapour flow and by special devices.

Within the range of conditions studied, defective as well as sound coatings were obtained, and there was a good deal of variation in the range of sound coatings between just acceptable and extremely good quality. The basis of assessment was mainly ductility. Bend test values from less than one bend through 90° to as much as 20 bends through 180° were obtained.

Appearance, ductility, micro-hardness and structure varied considerably and often unaccountably. Bright

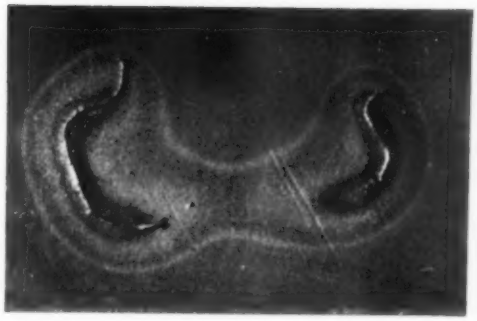

Fig. 34.—Effect of fluff or hair on the surface during plating. × 6

coatings with medium size compact grains were frequently the most ductile. Brittleness was most frequently found in matt coatings with fissures or loose grains or oxide structures; coatings with large grains usually had low hardness values, those with small or with microscopically invisible grains had high hardness values and low ductility. Dendritic, fine grained, and fibrous types of structure were most frequently obtained. All deposits except those heavily oxidised during plating underwent recrystallisation on heat treatment to give a polygonal equi-axial type of grain. Temperature was the most critical of the variables. Deposition at temperatures below 200° C. was accompanied by specific defects in the coating—darkness in colour and a velvety or powdery appearance, brittle fissured dendritic type of structure, and low deposition efficiency. As the temperature was increased from 200° C. up to about 230° C., the deposit improved in appearance and properties according to conditions (size of and geometry of specimen and bell jar, rate of flow, pressure, etc.) and at about 250° C. black powdery deposits formed on the bell jar and in the vicinity of the specimen. The optimum plating temperature was probably the maximum that could be used without black powder formation, but not less than 210° C. and, for best thickness distribution of coating, possibly not more than 230° C.

Rate of flow of nickel carbonyl vapour and pressure did not appear to be critical factors, although they have not been investigated independently of one another. High rates of flow and pressures much above 2–3 mm. seemed to result in coatings of less satisfactory appearance and increased tendency to black powdery decomposition of the carbonyl vapour, but it was nevertheless an outstanding feature of this process that plating rates of up to 20×10^{-3} in. per hour could be employed without drastic deterioration of coating properties. Conditions where particle formation in the vapour phase is of a low order would appear desirable for coatings of the best quality. It is not possible to say how these conditions can be determined, but low pressures, high linear velocities of vapour, and additions of carbon monoxide are probably favourable factors. The direction of vapour flow, i.e. upward or downward, affected the distribution of coating thickness. Diluent gases did not appear to exert marked beneficial effects, with the exception of carbon monoxide, which inhibited black powder formation and resulted in certain conditions in improved coatings. Oxygen in the nickel carbonyl vapour profoundly affected the properties of the coating, extreme brittleness, drastic increases in hardness, and a charac-

teristic banded type of microstructure being observed.

Further investigations aimed at securing conditions of plating giving the best quality deposits have been indicated in the discussion, and include effects of temperature, pressure, linear velocity, and added carbon monoxide. Factors determining the onset of mattness appear to have an important bearing upon ductility and merit attention. On the more fundamental side, vapour movement in the bell jar and the mechanism of deposition and film formation are to be recommended for study.

Attention will be required in any systematic investigation to devising means of controlling conditions throughout each experiment and maintaining uniform conditions from one experiment to another in a series. In some investigations, for example, the effects of pressure and/or linear vapour velocity on coating properties will require additional means to enable one variable to be adjusted independently of the other. In many instances it will not be possible to vary one factor entirely alone, and results may require some interpretation.

Acknowledgments

The author would like to thank Mr. E. G. Hall and various other colleagues at A.W.R.E., Aldermaston, who carried out the experimental plating operations and testing of coatings; also Mr. G. L. Hopkin O.B.E., Chief of Materials, and Mr. W. B. H. Lord, Senior Superintendent of Metallurgy, for their interest in the work.

APPENDIX A

Some Properties of Nickel Carbonyl

Nickel carbonyl is a transparent, slightly straw coloured liquid which boils at 43° C., melts at −23° C., and has a specific gravity of 1·32 at 17° C. It has a high vapour pressure at ordinary temperatures, 321 mm. at 20° C. and 134 mm. at 0° C. The vapour, which is highly toxic, decomposes on heating to yield metallic nickel and carbon monoxide; the reaction

$$Ni\ (CO)_4 \rightleftharpoons Ni + 4CO$$

being reversible to an extent depending upon conditions: the thermal decomposition has been studied by a number of workers.[8, 12, 13, 14, 15] The extent to which the vapour is dissociated depends upon the temperature and the extent of its dilution with other gases. Nickel carbonyl begins to dissociate at 36° C. and at 98° C., 5·8% is dissociated[16] at ordinary pressure; Mittasch[11] found that decomposition was rapid at 105° C. (90%), and according to Dewar and Jones[13] dissociation of the undiluted vapour was complete at 182° C. Carbon monoxide has a retarding influence on the rate of decomposition,[8, 14] and nitrogen is reported to lower the temperature at which decomposition is complete.[13] There is some reason for supposing that the decomposition takes place via an intermediate compound $Ni\ (CO)_3$, but this has little significance in this work. The side reaction

$$2CO \rightleftharpoons C + CO_2$$

can take place at temperatures within the plating range in the presence of finely divided nickel. Carbon is thus included in the nickel deposit, presumably in the form of Ni_2C.[17] The reaction takes place to a very limited extent below 250° C. Small quantities of air or oxygen decompose nickel carbonyl,[18] but larger amounts can form an explosive mixture according to temperature, pressure and the amount of oxygen present.[8, 18] The liquid carbonyl is slowly decomposed by moisture into green nickel carbonate and carbon dioxide.

APPENDIX B

Methods of Assessment of Coatings

B.1 Microstructure

Nickel coated specimens were prepared and examined for microstructure by the following procedure. The specimen was mounted in a thermo-setting resin using a metallurgical mounting press, followed by careful sectioning using a fine hacksaw blade with white spirit lubricant. The use of a lubricant lessened the risk of distortion of the coating or separation from the base metal as a result of undue stress. The selected section was then filed with a fine grade file until about 30–60 mil. had been removed, followed by preparation on emery paper of successively decreasing grit sizes to 000 grade. Polishing was carried out on a diamond dust impregnated pad using white spirit as a lubricant.

A 10% solution of hydrogen peroxide (20 volumes) in a 5% alcoholic solution of nital was used as an etchant, in addition to the more widely used mixture of nitric and acetic acids and water. This not only avoided excessive attacks where base metals such as brass and copper were included, but also avoided certain effects attributed to electrochemical action. It was generally considered a more suitable etchant for the carbonyl nickel deposits when in the unannealed condition.

B.2 Thickness Measurement

The American Magne-Gauge was employed for coating thickness measurement on all readily accessible surfaces where measurement was not required near edges in recesses or on thin sections. The microscope was employed additionally for thickness measurement where the magnetic thickness tester could not be applied. The specimen was usually "backed up" with a second layer of nickel to protect the edge during preparation.

B.3 Adhesion Testing

The test was applied to coatings of at least 2×10^{-3} in. in thickness on cylindrical specimens of the particular basis metal under consideration. The coating on one of the flat ends was first isolated from the remainder by filing the nickel away from around the edge of the cylinder until the base metal was exposed. A sharp instrument was then forced between the coating and basis metal and an attempt made to prize up a small piece for the purpose of obtaining a secure grip on the coating. The degree of adhesion was assessed qualitatively by the force required to detach it within a broad classification as follows:—

(*a*) Non-adherent—isolated portion fell off under gravity.
(*b*) Very weakly adherent—stripped off easily by the fingers after initially lifting up a suitably sized portion on which to take a hold.
(*c*) Weakly adherent—stripped off with difficulty by the fingers.
(*d*) Moderately adherent—stripped off easily with the aid of pliers.
(*e*) Fairly strong adherent—removed (usually in small pieces) with difficulty with the aid of pliers.
(*f*) Strongly adherent—cannot be completely separated from base metal even with the aid of a chisel.
(*g*) Very strongly adherent—no separation possible by mechanical means.

B.4 Porosity Testing

On steel the ferroxyl test was used, employing separate solutions of sodium chloride and potassium ferricyanide. A suitable type of paper, such as Whatman No. 541 filter paper, was soaked in an aqueous solution of 50 g./l. of sodium chloride and applied to the test surface of the specimen (suitably degreased) with the aid of gentle pressure for about 10 min. The paper was then removed and immersed in a solution of 10 g./l. of potassium ferricyanide for several minutes. After rinsing, white or blue spots indicate the presence of pores in the coating.

On aluminium a similar technique was used, employing solutions of different composition. Ammonium chloride solution (20% w/v) containing 1% w/v of gum arabic and 1% w/v Wettol was used instead of sodium chloride as the electrolyte. The time of contact was 2 minutes. Developing was carried out in a freshly prepared alcoholic solution of Aluminon (ammonium aurine tri-carboxylate). Discontinuities in the nickel coating were indicated by red spots on the paper after thorough rinsing in water. This method has not been extensively used, and unless carried out with special care is liable to give erratic results.

Usually two tests were made when porosity testing by these methods. If the number of pores or their distribution differed appreciably on repetition a third test was made. Further repetition of the test was avoided where the latter method was employed, since there was a general tendency for the pores to become blocked or masked, so that the porosity indicated was lower in each successive test.

B.5 Ductility

Qualitative assessment was made mostly on a portion of the stripped coating. The coating was held in a hand vice or pliers, the nose of which had been ground flat and a radius of about 10^{-2} in. ground on each edge, the coating was then bent to and fro through 180° until fracture occurred. Completion of each bend was assured as far as possible by applying gentle pressure with a flat object. Coating thickness was usually $2–3 \times 10^{-3}$ in. and endeavour was made to avoid wide differences in the thickness of the coatings to be tested.

B.6 Hardness

Micro-hardness testing was carried out on cross-sections of coatings mounted and prepared as described above. The etch was omitted, however, in instances where the definition of the indentation was thereby obscured; light etching was otherwise found to be helpful in deciding where to make the indentations.

The equipment used for measuring the hardness of the coatings was a bench type of micro-hardness tester designed by G.K.N. and manufactured by Hall Telephone Accessories, Ltd. The indentor was a standard 136° diamond pyramid mounted on a beam carrying a load which could be varied between 1 and 100 g. The beam and two microscope objectives were mounted on a common base, which was attached to the objective thread of a metallurgical microscope (Baker Met. 3). The base of the instrument could be rotated in the plane normal to the microscope tube, and by a suitable indexing device the indentor or either of the two objectives could be brought into the field under examination. Contact between the indentor and test surface was indicated by extinction of a neon light, the load being applied for a period of 15 seconds.

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C.I.B.A. Fellowship Awards

The Advisory Panel of the C.I.B.A. Fellowship Trust announce that the following Fellowships have been awarded for the academic year 1959–60:—

Dr. M. H. Richmond (Cambridge University and the Medical Research Council) to study at Copenhagen University (Microbiology).

Mr. V. P. Arya (Banaras University and London University) to study at the Polytechnic, Zürich (Natural products chemistry).

Mr. J. F. Counsell (Bristol University) to study at Göttingen University (Physics).

Mr. G. L. Duncan (Aberdeen University) to study at Louvain University (Polymer chemistry).

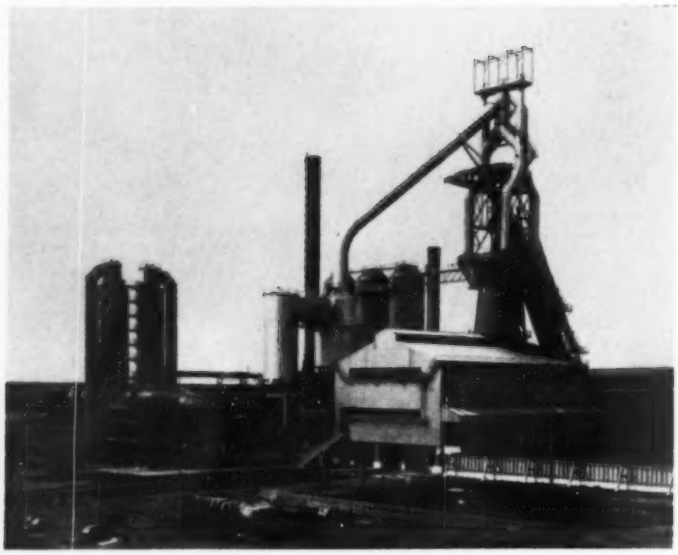
Mr. K. Jones (Sheffield University) to study at Heidelberg University (Organic chemistry).

Mr. B. L. Mordike (Birmingham University and Cambridge University) to study at the Max Planck Institute, Stuttgart (Physical metallurgy).

Specialised Brazing Service

Newton Victor, Ltd., the X-ray Department of Metropolitan-Vickers Electrical Co., Ltd., has recently introduced a new service to industry—specialised brazing. This service is being provided at the Department's Finchley Works, where specialised brazing plant is used in the manufacture of X-ray tubes and valves. It will be of particular interest to firms whose work would not justify the installation of costly equipment, and who might not have the necessary metallurgical experience. Such firms should address enquiries to Newton Victor, Ltd., 132–135 Long Acre, London W.C.2.

The plant provides for the high quality brazing of components in controlled atmospheres and under vacuum. It includes radiation and muffle furnaces, with which temperatures up to about 1,800° C. can be achieved, so that no torch or flame is needed; these furnaces will handle parts up to approximately 3½ in. square and up to 10 in. in length. There are also "eddy current" furnaces, which give fairly local heating and temperatures in excess of 1,100° C., and which are suitable for the brazing of circular components; these will deal with items up to 3½ in. in diameter and up to 3 ft. 6 in. in length. The joints catered for include stainless steel to stainless steel; stainless steel to steel; copper to steel; steel to steel; copper to copper; steel to Nilo K; and Monel to other metals. A method of brazing beryllium has also been developed, and applications for tungsten brazing can be investigated.



Margam's No. 5 blast furnace—one of the largest in the world.

New Blast Furnace Commissioned at Margam

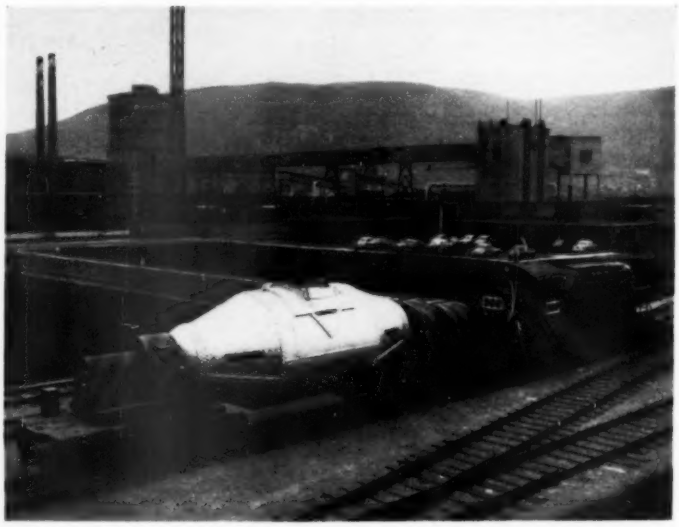
One of the Largest in the World

ON Friday, May 8th, Mr. Harald Peake, Chairman of The Steel Company of Wales, performed the lighting up ceremony which brought into operation at the Margam Works the new No. 5 blast furnace, one of the main items of plant to be installed under the Company's £52 million Development Scheme "M." The furnace, with a hearth diameter of 31 ft. and a working volume of 59,365 cu. ft., ranks by all accepted standards as one of the largest blast furnaces in the world. It has an iron making capacity of more than 10,000 tons per week.

No. 5 furnace, which is 248 ft. high, stands alongside the No. 4 furnace, which commenced operation in January, 1956. The stockyard which serves No. 4 has been extended to cover both furnaces and now has a total capacity of 250,000 tons of iron ore. Iron ore from the wharf and from the home ore tipplers reaches the stockyard by overhead conveyor, and its distribution over the stockyard is achieved by means of a stocking out bridge. A reclaiming bridge lifts the ore from stock and deposits it on to a conveyor system to be carried to the bunkers. As the weekly requirements of foreign ore will be in the region of 63,500 tons per week, a fifth transporter unloader has been installed at Margam Wharf. An important feature of the new furnace is that the layout makes it possible to operate entirely on sinter if this is required in the future. For this purpose, a conveyor system links the ore preparation plant direct with the sinter bunkers at No. 5 blast furnace.

Air for the furnace is provided by a 125,000 cu. ft./min. axial-flow turbo-blower, and to preheat the air there are three 140 ft. high stoves, each fitted with automatic valve change. The stove shells, furnace top, gas cleaning plant and mains have been designed for possible high top pressure operation.

When the furnace is tapped, iron will be run into 180 ton capacity torpedo mixer ladles, each 55½ ft. in length. These ladles are fitted with their own tipping equipment powered by a 15 h.p. electric motor, and the use of them will speed up the transfer of iron from blast furnace to melting shop. The slag from the furnace will be run straight into pits alongside the furnace. From these pits it will be loaded by mechanical digging equipment into heavy road vehicles which will carry it to the tips. This is similar to the method of slag disposal on No. 4 furnace.



One of the 180-ton capacity torpedo mixer ladles transferring molten iron to the melting shop

Owing to the nature of the ground on which the furnace and ancillary plant stands, it was necessary to drive 181 special piles to support the foundations. These piles, some of which were 39 in. in diameter and others 35 in., were driven to a depth of 70–80 ft. For the construction of the furnace foundation block, 9,680 tons of concrete were used, including 1,000 tons of refractory concrete. The portion of the foundation block below ground is constructed of sulphur resisting cement to counter any attack by ground water which may be contaminated by the nearby slag pools.

The furnace is carbon lined to lintel level, and in the hearth has carbon side walls with a refractory centre. 2,700 tons of steel were used for the construction of the furnace itself, and 390,000 bricks went into its lining.

Since No. 4 blast furnace commenced operation in 1956, it has produced more than 1,392,000 tons of very high quality iron, and is now due for a routine re-line. It is therefore intended to take No. 4 out of operation for re-lining as soon as No. 5 settles down to production. For this reason, the 80 new coke ovens which have been installed at Abbey Works, in anticipation of five blast furnace operation will not be brought into production until No. 4 furnace is ready to go into commission after re-lining.

Vitreous-Enamelled Aluminium

A New Architectural Material

General view of the Dolphin Court block

DOLPHIN COURT, Hove, lies on the north-east corner of a road junction a few yards north of the sea front. Its main aspects, therefore, are south and west, and it was recognised by the architects from the beginning that balconies would be an important feature of the block. In the design of these balconies three qualities were borne in mind, texture, colour and permanence.

A number of materials were considered for the decoration of the balconies, and aluminium was eventually selected by the architects as combining physical lightness with interesting possibilities, from the fabricating aspect, of producing the appearance, as well as the fact, of lightness. The pattern chosen (1 in. wide flutes at 2½ in. centres) admirably succeeds in this. The smooth texture of the panels, moreover, is an excellent foil for the various facing bricks used.

The question of colour is perhaps an even more important one. The two colours used, a greenish blue and a pale yellow, are not available in colour anodising ; this leaves as possibilities painting and stove- or vitreous-enamelling. The last-named was chosen because it provides a finish combining high lustre with freedom from deterioration, even in the marine environment of Hove. Combined with aluminium, vitreous enamelling is even more permanent ; the bond between enamel and metal will resist minor damage, and even severe knocks with local exposure of the metal will not give rise to progressive deterioration.

The panels, pressed by William Rowe (Fabrications), Ltd., in metal supplied by The British Aluminium Co., Ltd., were vitreous-enamelled by Ernest Stevens, Ltd., who are well-known in the vitreous-enamelling field as the makers of Judge ware. The vitreous-enamelled aluminium products of the company are marketed under the trade name Judgelite.

The Vitreous-Enamelling Process

The plant in which Judgelite is produced comprises chemical pre-treatment tanks, spray booths, and a 250 kW. electric furnace of the resistance type.

Primarily pre-treatment is carried out in caustic soda and nitric acid with intermediate washings, but can be modified to suit specific requirements. Due to the nature of the work called for in this process the sheets are treated in batch fashion by means of overhead transfer conveyor, culminating in a final water rinse when the oxide film has been built up to the pre-firing stage, in which the sheet to be enamelled is passed into the furnace for a predetermined period to complete the build up of the oxide film.

View of balcony incorporating vitreous-enamelled panels.

The enamel is sprayed manually or automatically on to the panels, dependant upon the form which they take ; they are subsequently re-introduced into the furnace along a driven roller table at pre-determined speeds of travel appropriate to the nature of the work. The work is timed through the furnace which is held at a closely controlled temperature throughout, in order to achieve the requisite bond strength and to maintain uniformity of colour. Fusing of the enamel to the aluminium is achieved at approximately 540° C.

The furnace itself is 20 ft. long × 4 ft. 6 in. in width, and fans are positioned in the roof to assist in maintaining temperature uniformity throughout. The work is laid flat in its travel through the furnace, but by suitable jigging arrangements it is possible to achieve a perfect finish on the back and front. Again, by the use of firing jigs, the 4 ft. 6 in. width of the furnace can be exceeded, and up to 5 ft. width can thus be accommodated. This type of furnace construction permits of continuous feed of long sheets through the furnace, so that sheet length is not limited to the furnace length of 20 ft.

Fundamentals in the process are clean metal, free of inclusions and with a good mill finish ; clean chemical solutions ; and a clean dust-free environment.

Iron Castings in Steam Engineering

THE standard practice in this country for iron castings used for steam applications where dimensional stability is important, such as in steam turbine engineering and for valves and for pipe fittings, is to limit the temperature to below 232° C. (450° F). For some time designers and engineers have considered this temperature unrealistic in view of the technological advances made in the production of iron castings. The question of raising this specified limiting temperature is important, since with more efficient steam plant operation, higher temperatures and pressures are used, and there is a danger that iron castings may be replaced by other materials for no valid technical reason.

In America, there is a standard A.S.T.M. specification for grey iron castings for pressure-containing parts for temperatures up to 343° C. (650° F.). This specification was prepared in conjunction with the American Society of Mechanical Engineers and represents standard practice for boiler and pressure vessel applications. In the United Kingdom, in a few isolated cases where foundries have been proved to have satisfactory control, the use of cast iron for valves at temperatures up to 316°C. (600°F.) and at pressures not greater than 300 lb./sq. in. has been sanctioned. Such castings are subject to very rigorous tests before acceptance, and to pressure tests at 450 and 500 lb./sq. in. However, iron castings for some applications at temperatures above 232° C. (450° F.) will not at present be generally accepted.

Growth Tests

The dimensional stability of iron castings is determined by their growth and creep resistance, provided they have been given an appropriate stress-relieving heat treatment before service. To supply the necessary data to permit the various authorities to raise the present temperature limit, an extensive programme is being carried out by the British Cast Iron Research Association to evaluate the growth and creep characteristics of a very wide range of iron castings. The results of the growth tests carried out in this programme have now been fully reported.*

Growth and scaling tests were carried out on 35 cast irons, including 20 flake graphite cast irons, 14 nodular cast irons, and a blackheart malleable cast iron. Unalloyed pearlitic flake graphite cast irons with various carbon, silicon, manganese, sulphur and phosphorus contents, and alloyed irons containing nickel, chromium and molybdenum, have been studied. The as-cast and annealed ferritic nodular cast irons used were produced from various raw materials and contained various alloying and trace elements.

No growth was recorded in any materials at 400° C. (752° F.) and below, in tests of up to 64 weeks in air and up to 49 weeks in steam. These results confirm the view that the present limiting temperature is unrealistic, and that a temperature of 343° C. (650° F.), similar to that used in America, would be satisfactory. This temperature is still considerably below that at which growth was detected in the tests carried out.

Mechanical Tests

Tensile and hardness tests carried out on specimens exposed in air and steam confirmed that all cast irons were structurally stable at temperatures of 400° C. (725° F.) and below, for the periods mentioned. No change in tensile strength and hardness was revealed in irons exposed at this temperature. Short-time, high-temperature tensile tests were carried out on all materials, confirming the results of other workers and showing that cast iron retained its strength at 400° C. (725° F.) and below.

Growth data are of primary importance, since dimensional stability is expected to be influenced by growth rather than by the magnitude of the stresses applied. However, though stresses are generally low, creep tests are also in progress to supplement the growth data already established, and the results of these will be reported shortly. It is anticipated that active steps will then be taken to modify the present limits for service conditions of iron castings in steam engineering.

* *B.C.I.R.A. Journal of Research and Development*, 1959, **7**, 478-566.

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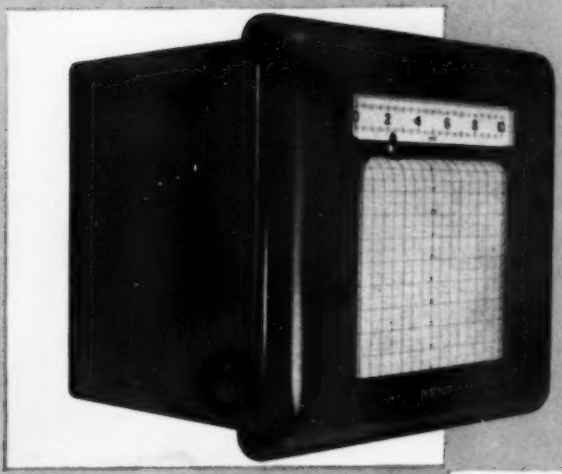

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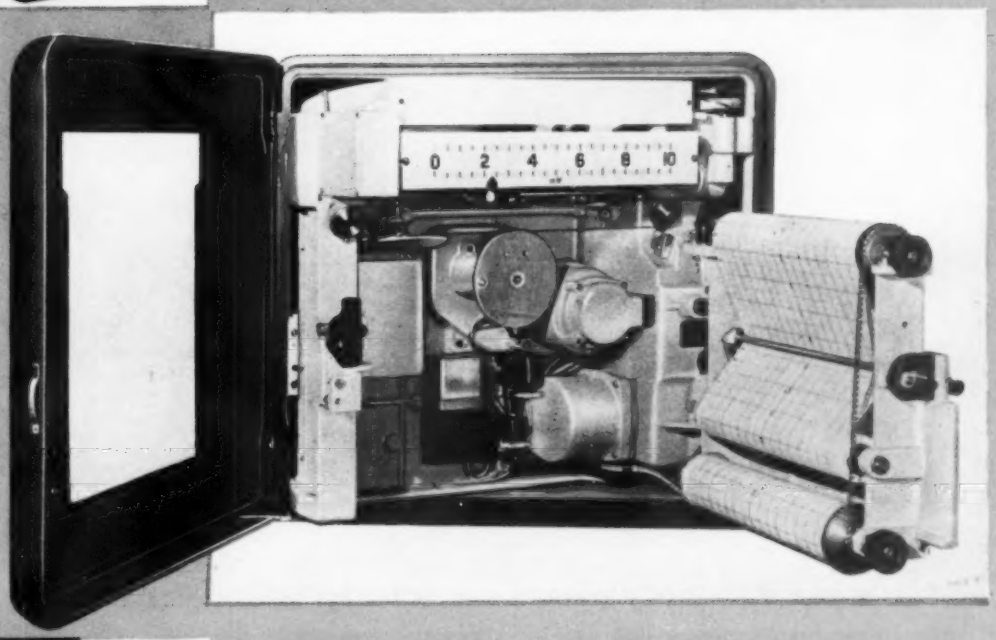

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NEWS AND ANNOUNCEMENTS

Symposium on Aluminium in Building

A SYMPOSIUM on Aluminium in Building has been arranged by the Aluminium Development Association for Thursday and Friday, July 9th and 10th, 1959. It will be held at the Royal Institute of British Architects, 66 Portland Place, W.1. by courtesy of the President and Council of the Institute. There will be three sessions for discussion: (*a*) Aluminium as a Building Material; (*b*) Aluminium Curtain Walling; and (*c*) Aluminium Building Applications. In the course of these sessions some fourteen papers will be introduced, reporting in detail the advances made—some of them very recent and significant to future trends.

The principal objects of the Symposium are to provide a forum for the free exchange of views between architects and builders on the one hand, and the aluminium industry on the other; to receive suggestions and criticisms which will help to develop further new items by the aluminium industry and manufacturers; and to indicate future possibilities for extending the usefulness of aluminium in this important field of application.

Papers will be sent in advance to those registering for attendance. At the Symposium, the papers at each session will be introduced by a rapporteur, so that maximum time will be available for discussion and for replies by the authors. Requests for invitations to attend are open to architects, builders, contractors' engineers and others with qualifications and experience in the building industries. Early application to The Aluminium Development Association, 33 Grosvenor Street, London, W.1., is advised, as accommodation is limited.

The Iron and Steel Institute

Changes in Council

THE following elections to the Council of the Institute took effect at the Annual General Meeting last month.

President: MR. W. BARR, O.B.E.

Honorary Treasurer: SIR JULIAN PODE.

Vice-Presidents: MR. B. CHETWYND TALBOT, and MR. C. H. T. WILLIAMS.

Ordinary Members of Council: MAJOR W. R. BROWN, D.S.O., and MR. T. R. CRAIG, O.B.E., T.D.

Additional Honorary Members of Council: DR. N. P. ALLEN, F.R.S., and MR. A. JACKSON.

Summer School on Corrosion

THE Sixth Summer School on Corrosion will be entitled "Newer Materials for Resistance to Corrosion" and will be held in the Metallurgy Department, Battersea College of Technology, from September 28th to October 2nd, 1959, inclusive. The lectures, given by authorities in their particular field, will deal with newer materials, metallic and non-metallic, for resistance to aqueous and high temperature corrosion. The topics will include: design in corrosion, nickel alloys, stainless steels, titanium, zirconium, tantalum, precious metals, plastics and coatings of plastics, fibre-glass, paints etc. The course should be of particular value to chemical and corrosion engineers and metallurgists who are desirous of obtaining up-to-date information on developments in this field. Ample opportunity will be allowed for questions and discussions. The fee for the course is 12 guineas' including lunch and refreshments. Applications should be made as soon as possible to the Secretary (Summer School) Battersea College of Technology, Battersea Park Road, London, S.W.11.

Non-Destructive Testing Course

AN Evening Course of ten lectures on "the Techniques of Non-Destructive Testing" will be held in the Physics Department of the Brunel College of Technology, Woodlands Avenue, Acton, London, W.3, every Wednesday from 7 p.m. to 8.30 p.m., commencing on Wednesday, October 7th, 1959. Lectures will be given by well-known specialists in the subject, and by members of the College staff. These will be of interest to inspectors and others engaged in the work, and also to graduates and holders of the H.N.C. in engineering and science subjects, who require an introduction to the methods employed in non-destructive testing. Further details of the course, for which the fee will be £1, may be obtained from the Physics Department at the College.

Institution of Metallurgists

Election of Officers

AT the Fifteenth Annual General Meeting of the Institution of Metallurgists on May 12th, 1959, the following elections were made

President: PROFESSOR A. J. MURPHY, Principal, College of Aeronautics.

President-Elect: MR. W. E. BARDGETT (United Steel Companies, Ltd.).

Vice-Presidents: DR. W. O. ALEXANDER (Imperial Chemical Industries, Ltd. (Metals Division)) and PROFESSOR J. W. CUTHBERTSON (University of Nottingham).

Hon. Treasurer: DR. E. G. WEST (Aluminium Development Association).

Ordinary Member of Council elected by Fellows: MR. L. ROTHERHAM (Member for Research, Central Electricity Generating Board).

Ordinary Members of Council elected by Associates: DR. C. S. BALL (Chief Metallurgist, Steel Division, The Steel Company of Wales, Ltd.), MR. D. LEWIS (Principal Scientific Officer, Research and Development of Materials Branch (Air), Ministry of Supply) and DR. I. G. SLATER, (Head of Metallurgy Department, College of Technology, Birmingham).

Die Casting Exhibition

THE Zinc Alloy Die Casters' Association in conjunction with the Light Metal Founders' Association is sponsoring an international exhibition of pressure die castings open to the public at the Birmingham Exchange and Engineering Centre, Stephenson Place, from June 15th to 19th (10 a.m. to 7 p.m.). The castings to be shown will be in

zinc alloy and in aluminium, magnesium, tin and copper alloys, and are drawn from the U.K. and many European countries, including France, Belgium, Holland, Italy, Denmark, Sweden, Germany and Switzerland. The die castings have been provided by members of the European Pressure Die Casting Committee, and will be displayed afterwards in the main industrial centres of Europe. They represent a wide range of applications, designs and finishes, and illustrate many new aspects of die casting, including some examples of vacuum die castings. The exhibits range from miniature, intricate parts to large crank-cases and gear-boxes. The exhibition will be of great interest to all those wishing to improve the efficiency and design of their products and lower manufacturing costs.

Light Alloy Refiners and Smelters

At the recent First Annual General Meeting of the Association of Light Alloy Refiners and Smelters, Ltd., Mr. R. Hahn (B.K.L. Alloys, Ltd.) was appointed Chairman and Dr. J. Jakobi (International Alloys, Ltd.) Vice-Chairman. The Council of Management consists of the Chairman, the Vice-Chairman, and the following members: Mr. F. Farenden (The Eyre Smelting Co., Ltd.), Mr. W. W. Kee (Enfield Rolling Mills (Aluminium), Ltd.), Mr. E. W. Nicholls (The Wolverhampton Metal Co., Ltd.), and Mr. P. Ward (John Dale, Ltd.).

National Engineering Laboratory

The Council for Scientific and Industrial Research announces that in future the Mechanical Engineering Research Laboratory at East Kilbride, near Glasgow, will be known as the National Engineering Laboratory. This is because the Council considers it desirable to emphasize the national character of the Laboratory, which is part of the D.S.I.R. organisation and is financed from public funds. It does not imply any change in the field covered by the Laboratory, which will continue to be concerned with problems of mechanical engineering. As a result of a recent review of the functions and activities of the Laboratory, the Council is convinced that, between the proper and reasonable activities of the universities and technical colleges on the one hand and research associations and private and nationalised industry on the other, there is an important place for a national establishment for research in mechanical engineering, mainly supported by public funds.

Spanish Aluminium Strip Mill

The installation of a cold strip mill for aluminium has just been completed at the Alicante Works of Aluminio Iberico, S.A., the Spanish associate of Aluminium, Ltd., of Canada. This follows closely on the completion of a hot mill in November, and brings the plant's annual capacity to 18,700 tons of semi-fabricated aluminium products, including 13,000 tons of sheet products.

Construction of the $10 million plant at Alicante, started in 1954, with plans to produce cable, extrusions, rod, bar, tubing, sheet and strip, with modern equipment. The cable mill, with a current capacity of 4,400 tons per year, came into production in 1956, with standard wire and cable products. An extrusion press of 1,300 tons capacity was installed, and a second press, now on order, will increase the extrusion capacity to 3,700 tons by next year.

Conference Report

A report of the Conference on Metallurgical and Engineering Aspects of Weight-Saving in Steel Structures, organised by the West of Scotland Iron and Steel Institute, and held in May of last year, is almost ready. It comprises 197 pages containing the full text of all the papers read and the discussion thereon, and will form Vol. 66 of *The Journal of the West of Scotland Iron and Steel Institute*. Copies—price 42s. paper bound and 47s. cloth bound—may now be ordered from the Secretary of the Institute, 39 Elmbank Crescent, Glasgow, C.2.

Delapena Move

Delapena & Son, Ltd., manufacturers of induction heating and honing equipment, have now moved the major part of their administrative staff to new offices in Cheltenham. The address is Tewkesbury Road, Cheltenham., Glos., and the telephone number of the new offices is Cheltenham 56341 (Telex 43354). These offices house the directors, the general administrative staff, sales and accounts departments. The factory remains at Zona Works on the present site, along with drawing offices, works management and advertising departments. The phone number of the factory premises is Cheltenham 54653. The new offices are built on a 7-acre site to which a complete new factory to occupy 50,000 sq. ft. will soon be added.

Handbook on Inert-Gas Arc Welding

The Inert-Gas Arc Welding Panel of the Institute of Welding is preparing a special handbook which will deal with the welding of a large range of engineering materials by the inert-gas arc welding processes.

The handbook will be in two parts, the first of which review the processes available and their applications and will deal with the safety precautions necessary in using these processes. The various sections of Part II will each be concerned with group of alloys, including those of aluminium, nickel, copper, magnesium and titanium, carbon steels, heat and corrosion resisting steels, and special materials such as zirconium and tantalum. Information given about the principal alloys of each group will include their mechanical, physical and relevant chemical properties; forms in which they are available; notes on manufacturing history; guidance on the selection of welding processes and joint details; welding procedure; and weld properties.

Chemical Analyses

of Ferrous and Non-Ferrous Metals and alloys, ores, slags, minerals, etc.

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RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Mallory No-Chat

JOHNSON MATTHEY & CO., LTD., announce that they are now producing and marketing in Britain Mallory No-Chat, a sintered tool shank material possessing characteristics that have gained it wide acceptance in precision machining in the U.S.A. It has an exceptional combination of physical properties: a modulus of elasticity of 40×10^6 lb./sq. in., a density of 16·95 g./cc. (0·606 lb./cu. in.); a coefficient of linear expansion (100–200° C.) of 5×10^{-6}/° C., together with an ultimate tensile strength of 112,000 lb./sq. in.

Its higher modulus of elasticity, and hence greater rigidity, combined with the high density and inherent vibration damping capacity of the material, mean that tools with shanks fabricated from No-Chat will produce better surface finishes than steel-shanked tools of identical size, with a minimum of chatter. Moreover, because of the reduced tendency to chatter, tool-tip life is considerably increased, even in the most rigorous conditions of service. Optimum results with tungsten carbide tools are obtained by using high speeds with deep cut and light feed and it is claimed that by employing tools with No-Chat shanks each of these factors can be increased.

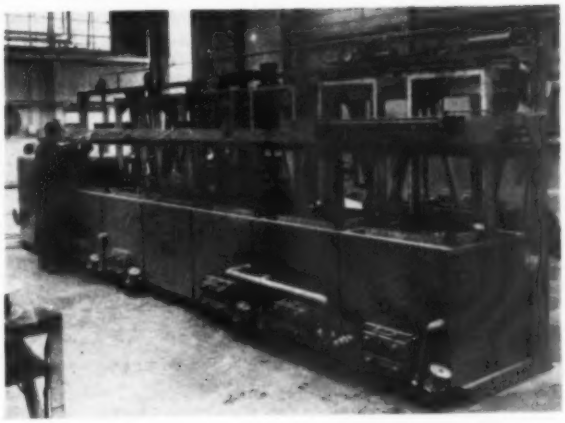
The coefficient of thermal expansion of No-Chat (half that for steel) is about equal to that for tungsten carbide. Tip cracking through thermal stresses in brazing the tip onto the shank, or in service, is thus avoided. Furthermore because No-Chat does not anneal, even at high temperatures, there is no need to dispense with the shank once the tool tip is worn out. The tip may be removed from the shank and a new tip brazed on without any effect upon the physical properties of the shank.

These advantages apply to all turning tools, but No-Chat is also an ideal material for boring bars and grinding quills, where the greater rigidity and higher damping capacity are particularly valuable. In general it may be said that when it is necessary to have an extended tool overhang, a thinner shank, higher cutting speeds or deeper cuts, the benefits to be derived from the use of No-Chat are brought into special prominence.

Johnson Matthey & Co., Ltd., 73–83 *Hatton Garden, London, E.C.*1.

Automatic Pre-Treatment Plant

THE Agi-Dip fully automatic multi-stage pre-treatment plant that has just been introduced by the Electro-Chemical Engineering Co., Ltd., is very flexible in design and can be used for various types of cleaning and process treatments, including pickling and phosphating, on a wide variety of ferrous and non-ferrous metal components. In this type of plant, the parts to be treated are loaded into baskets which are then automatically passed through agitated immersion stages, the number of these depending on the treatment required. Trichlorethylene vapour degreasing, spray rinsing and drying sections can be incorporated into the sequence if required.



Agitation is carried out by means of a reciprocating pneumatic arrangement that is adjustable for amplitude and frequency of stroke. Double acting air cylinders enable the work platforms to be driven down into the solutions at a faster rate than the freely falling components, thus effecting complete separation of tightly packed parts. The work is transported through the sequence by means of an index beam conveyor controlled by a timing mechanism. This mechanism can also operate automatic loading and unloading platforms to link the plant with a shop conveyor. Only one operator is normally required for the plant.

Electro-Chemical Engineering Co., Ltd., Sheerwater, Woking, Surrey.

Metallurgical Powder Dispenser

EQUIPMENT to introduce fluxes into the body of a melt to permit reactions to take place more rapidly and with greater efficiency has been developed by the British Oxygen Co., Ltd., Known as the B.O.C. Metallurgical Powder Dispenser, it has been designed for foundries, melting shops and general metallurgical use, and is based on the principles of the company's existing dispensers, which are already widely used for the injection of metal powders for gas cutting.

Previously, in melting metals and alloys, it has been necessary to rely on additions at the surface which react slowly and are relatively ineffective. The reason is that the reaction zone is limited to the area of surface contact between slag and metal. A further limitation is provided by the slow rate of diffusion of some of the reacting substances. Metallurgists have appreciated the value which would arise from the introduction of powdered slag-making materials into a metal, but until now there have been no simple methods of injection.

The scope for the new dispenser is considerable, and it has already proved that dispensing techniques can be of great value in the manufacture of cast iron. Desulphurisation with calcium carbide and recarburisation

with powdered graphite are two processes which are technically and economically successful. Both these materials are injected by means of a stream of nitrogen, and the powder enters the metal through a graphite or refractory lance. The treatment may be carried out in the ladle following melting, and also directly in high frequency induction furnaces. The treatment may also take place following melting or during storage in any other type of unit. Sulphur may be removed with calcium carbide, virtually to any required value, although the usual minimum is 0·02%. The treatment time is of the order of one or two minutes, depending on the metal weight and degree of desulphurisation required. A dry, easily removable slag consisting mainly of unfused lime is produced. There is no pick-up of nitrogen by the melt, and, in fact, some evidence suggests an improvement in mechanical properties due to the refining of the structure of the iron.

Recarburisation is carried out using graphite in a stream of nitrogen. The process is normally applied for treating iron with an initial carbon content of at least 3·0%, but it is of course equally suitable for irons of lower carbon content. A final carbon of up to 4·0% can be obtained quite rapidly. The efficiency of the carbon pick-up is particularly high, and may approach 100%. There is considerable scope for this process in the manufacture of high carbon iron, and in the recarburisation of melts produced from high proportions of steel or cast iron scrap. Here, the ability to recarburise offers a most economic prospect, because of the difference in cost between pig iron and scrap.

By using mixtures of calcium carbide and graphite, it is quite simple simultaneously to desulphurise and recarburise. Apart from these established uses, some of the prospective applications appear very promising. A wide range of powders can be handled by the dispenser, and the use of some of these may make it possible to produce substantial modifications to the structure of cast iron.

Capacity of the hopper is approximately 2 cu. ft., and it holds 150 lb. of calcium carbide or 100 lb. of graphite, which can be used as required : it is not necessary to use the full charge in one operation. Discharge rate of the powders is up to 30 lb./min. depending on the pressure applied. The equipment can deliver either gas or gas and powder with selection by lever movement.

British Oxygen Co., Ltd., Bridgewater House, Cleveland Row, St. James's, London, S.W.1.

Transformer Welding Plant

PHILIPS ELECTRICAL, LTD., announce the addition of three new models to their range of arc welding transformers. The Type ES.1370 gives an output of 65 A., for welding with 14 s.w.g. electrodes, and is especially suitable for the welding of sheet metal and light gauge steel—18 s.w.g. upwards to $\frac{3}{16}$ in., and slightly heavier material in multiple runs. In addition, brazing of very thin sheets and steel sections can be carried out by means of a special 10 V. tapping. It is particularly recommended for the small workshop or garage.

Designed as a general purpose set for all light, medium and medium-heavy welding operations, the Type ES.1371 transformer operates on the voltage range 190–500 A.C., 40–60 c./s., and has provision for sixteen different tappings of welding current. Maximum output : high current—175 A., 16/8 s.w.g. electrodes—continuous ; low current—130 A., 16/10 s.w.g. electrodes—continuous.

The Type ES.1372 machine can be used by one operator for operations calling for up to 350 A., or by two operators up to 175 A. each. When used by a single operator, the transformer is suitable for all heavy welding requirements. It operates on the voltage range 190–500 A.C., 40–60 c./s., and has provision for sixty-four different tappings of welding current. Maximum output : (1 operator) high current—350 A., 16/4 s.w.g. electrodes ($\frac{1}{4}$ in. intermittent) ; (1 operator) low current—260 A., 16/6 s.w.g. electrodes—continuous ; (2 operators) high current—175 A., 16/8 s.w.g. electrodes—continuous ; (2 operators) low current—130 A., 16/10 s.w.g. electrodes—continuous.

Industrial Equipment Division, Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

Precision Casting Investment Base

A NEW type of investment base for precision investment casting, developed by Mellor Mineral Mills, Ltd.—one of the Dohm Group of Companies—is being marketed under the trade name of Investment Base 350. Originally confined to the jewellery industry, the new method is now being used by a number of foundries for the production of precision castings where machining cannot be carried out, and where surface finish and tolerances are important. It was developed after extensive tests based on the original American cristobalite base. According to the manufacturers Investment Base 350 operates at a temperature of 1,450°C. It needs no additives, retarders or accelerators, only water to mix into a slurry : setting time is 20 minutes.

Mellor Mineral Mills, Ltd., Etruria Vale, Stoke-on-Trent.

Pilot Dryer

DESIGNED specifically to dry air and gases for transistor manufacture, atomic energy pilot plant, furnace atmosphere dewpoint control, stainless steel brazing and general process use, the new Birlec pilot dryer, introduced at the International Transistor Exhibition, weighs 75 lb., and is a readily portable unit for drying air and process gases on a pilot scale. It may be supplied with various desiccants, depending upon the intended application. For most common applications, the desiccant material of widest value is activated alumina ; for other requirements, molecular sieve adsorbent, silica gel or aluminium silicate may be preferred. The dryer is complete with two valves for the main flow, and two for the reactivation flow, two thermometers, pressure gauge, heater warning light and switch. For drying purposes, the unit is connected in circuit until the desiccant becomes saturated, whereupon it is removed from circuit and reactivated by a built-in heater system.

With a desiccant capacity of 0·25 cu. ft., the Birlec pilot dryer is basically a round-ended cylinder of diameter 9 in., and height 3 ft. 2 in. The reactivation temperature can be controlled at any desired level between 100°C. and 300°C. Reactivation heating takes some 2½–5 hours, and a cooling period of 2–3 hours is necessary. It is believed that this new design will meet most of the requirements for pilot plant and similar small scale drying of gases for research and industrial use.

Birlec, Ltd., Erdington, Birmingham, 24.

CURRENT LITERATURE

Book Notices

METAL FATIGUE

Edited by J. A. Pope. 381 pp., including index and numerous illustrations. London, 1959, Chapman & Hall, Ltd. 70s. net.

THIS volume contains the lectures given during a week's residential course on the fatigue of metals held in the Engineering Department of the University of Nottingham in September, 1955. The object of the course, and hence of the book, is to present to the engineer and designer the known facts about metal fatigue, so that due account may be taken of these aspects during design. There is no doubt that this objective has been attained.

The book consists of three parts, the first dealing with the fundamentals of fatigue, the second with the fatigue properties of engineering materials, and the third with the methods of fatigue testing. Each chapter in each section represents one lecture, and the authors were chosen from the university and from industry for their specialised knowledge in a particular branch of the subject. A certain amount of overlapping between chapters is inevitable with this method of presentation, but this does not detract from the value of the work, and on the contrary may, by the resulting expression of differing points of view, be an advantage. A most gratifying feature is the care which has been taken in editing to ensure consistency of the terms used, and a list of the symbols used throughout all the lectures is included in the front.

The part devoted to the fundamentals of fatigue covers the theory of fatigue failure, failure under complex stresses and stress raisers, the effect of residual stress on fatigue failure, and the cumulative damage in fatigue. It is a clear and concise explanation of the principles involved which can be readily assimilated. The effects and cause of corrosion fatigue are also dealt with, and a useful appendix on the very important aspect of statistics as applied to fatigue testing is included.

Part II is of value to the practising designer and engineer, and gives the fatigue properties of the common materials used in engineering at normal and at elevated temperatures. Much test information is published showing the behaviour of aluminium alloys, high temperature alloys, cast iron, bronzes and bearing materials under various forms and levels of stress. Complete chapters are devoted to the fatigue properties of joints and welds, though the book emphasizes the scarcity of fatigue information on welded aluminium alloys.

In Part III, the difficulties in fatigue testing and the reproducibility of results are discussed. The four general methods of fatigue testing in common use today are dealt with, namely resonance vibration, constant load, constant strain, and pulsating pressure. A useful introduction to these aspects of the subject is given, together with a review of some of the machines in use, and their limitations. The design of fatigue testing machines is a highly specialised field, and the broad outline which is given is adequate for a book of this kind. Some examples of hydraulic oscillators as applied to fatigue testing are given, and this method of conducting fatigue testing has much to commend it.

"Metal Fatigue" is one of the few books on the market which is completely devoted to fatigue, and it presents to the reader the knowledge which has been accumulated on this subject. It is of use not only to students who may feel that their course of studies is deficient in this respect, but also to experienced designers and engineers.

THE DETERMINATION OF NITROGEN IN STEEL

Special Report No. 62 of the Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W.1. 146 pp., including 63 pp. of tables, 9 appendices and 4 pp. of illustrations. 37s. 6d. (25s. to members of the Institute).

GREAT interest has always been shown in the role played by nitrogen in determining the properties of ferrous alloys. Reliable and accurate methods are therefore necessary for determining the content of this element in such alloys. Despite the work in the past of the Oxygen Sub-Committee of the Heterogeneity of Steel Ingots Committee on the determination of nitrogen in steel, there have been many differences of view regarding the most reliable chemical procedure to be employed for any particular steel, and there has been a body of opinion which holds that the vacuum-fusion method tends to give nitrogen results which are low by about 0·002%. In view of this unsatisfactory aspect of the two methods of determination, the Gases and Non-Metallic's Committee of the British Iron and Steel Research Association set up, in 1949, the Nitrogen Group to re-examine the whole subject of the determination of nitrogen in steel. This report gives the results of the Group's work.

The first part of the report deals with the chemical methods of analysis. A series of steels each containing one main alloying element was studied in respect of the applicability and reproducibility of various chemical methods currently in use. The investigation confirmed that once the sample has been decomposed without loss of ammonia, a wide choice of methods is available. It also enabled a classification of alloying elements to be made between those which can lead to the formation of acid-resisting nitrides—thus rendering non-fuming chemical methods inapplicable—and those which do not form such nitrides. As a result of the statistical study of all the results by fuming methods, the Group has put forward tolerance limits for nitrogen results obtained by chemical methods between laboratories and within a laboratory. A standard method for the chemical determination of nitrogen in steel has been put forward and has been accepted by the British Standards Institution.

Part II deals with the vacuum-fusion method as applied to the same steels. The results completely refute the suggestion that the method gives low results. On the steels studied, there is good agreement between methods, and no evidence that the different types of vacuum-fusion apparatus show any major difference in suitability for the determination of nitrogen.

The report also includes the record of an investigation of nitrogen determination in ferro-chromium, the results of which indicate that the normal chemical methods are applicable, even for contents of more than 2% found in certain grades of this ferro-alloy.

Trade Publications

FEATURED in the March–April issue of *B.T.H. Activities* is an article dealing with the electrical equipment supplied by B.T.H. for the continuous tinplate annealing line at the Velindre Works of the Steel Company of Wales. This line, which represents another step forward in the development of the continuous process of tinplate manufacturer in this country, is the first to be installed in Europe. Another article of metallurgical interest is that describing the production of transformer laminations in cold-reduced grain-oriented steel.

IT is over thirty years since The Pyrene Co., Ltd., introduced the first Parkerizing process to British industry. Since that time the now extensive range of Bonderizing, Parkerizing and other pre-treatment processes has found extensive application in all branches of light engineering, and a considerable background of technical knowledge has been accumulated, based on experience in the field, on research and development, and on the most up-to-date practice in all parts of the world. In a recently published booklet, the Pyrene Company sets out to show how this knowledge is available to customers in the form of engineering advice, after sales service, laboratory services, and plant, materials and ancillary equipment.

A NEW G.E.C. leaflet deals with Twyntorq motors which, by the transmission of static torque or power, can be applied to signalling or indicator duties and remote control systems. They can also be used to provide correction power for the purpose of synchronising equipment powered by individual driving motors with no mechanical interconnection. The publication provides a guide to the application, construction, operation and performance of the standard machines.

IN the belief that every business man in this country can gain a great deal from applied photography, once he is shown how, Kodak have recently published a booklet to show how the leading industrial and commercial firms and research organisations are using photography in their everyday operations. In the wide field of research, photography is used to magnify and record the microscopic, slow-down or stop ultra-rapid movement, measure phenomena invisible to the eye, and stretch or compress time to order. Numerous examples—but a few of the many that could be chosen—are presented, to illustrate these uses, and further sections of the booklet deal with cinematography and the use of photographic methods for the purpose of copying drawings, letters, etc. Another new Kodak publication deals with negative materials available for professional, commercial and industrial photography, in the form of sheet film, roll film, 35 mm. film and plates.

WITH increasing use of the spectrograph in industry, there is a growing demand for spectroscopists, and an article in the February issue of *Hilger Journal* deals with the subject of teaching spectroscopy, based on the Hilger and Watts constant-deviation wavelength spectrometer, a versatile and convenient instrument that has been comprehensively treated by C. Candler in his textbook "Practical Spectroscopy." A further article describes an automatic motor drive for plate racking on a Hilger Littrow spectrograph. This unit eliminates chance double exposures and greatly facilitates the taking of moving plate exposures to study relative rates of volatilisation when developing new procedures.

FOR 108 years Davy's Engineering Department was located at Park Iron Works, Sheffield, but the post-war growth of Davy and United Engineering Co., Ltd., has been such that the inefficient and obsolete premises could no longer contain the engineering staff necessary to support the volume of production of which the works had become capable. As soon, therefore, as the re-equipment of the production workshops had been carried out, plans were put in hand for the erection of a new block at Darnall Works, Sheffield, to serve as engineering offices and administrative headquarters. The company has now issued a booklet describing the planning and building because, as Mr. Fiennes the Managing Director, points out in a foreword: ". . . we felt that the conception and execution of this building contained many matters of interest and it seemed to us that there should be some record of the skill of those who designed and built this house."

THROUGHOUT industry precision iron castings are required with physical properties of a high order. To meet the need for castings to withstand hydraulic pressure up 2,000 lb./sq. in., and high duty irons with tensile strengths of 30 tons/sq. in. Incanite, a metallurgically controlled high duty cast iron was developed, and a new leaflet (V.11C) has recently been issued by The Incandescent Heat Co., Ltd., describing the properties of its four grades. Each grade has its own characteristic properties and there is a grade of Incanite to cover any requirement of B.S. 1452.

Books Received

"Elements of Physical Metallurgy." By A. G. Guy. 528 pp. Massachusetts, 1959. Addison-Wesley Publishing Company, Inc. $9.50.

"Metal Fatigue." Edited by J. A. Pope. 381 pp. inc. index and numerous illustrations. London, 1959. Chapman & Hall, Ltd. 70s. net.

"The Structure of Metals: A Modern Conception" Lectures delivered at the Institution of Metallurgists Refresher Course, 1958. 118 pp. Published for The Institution of Metallurgists by Iliffe and Sons, Ltd., in London, and New York. The Interscience Publishers, Inc. 25s. net.

"The Physical Metallurgy of Magnesium and its Alloys." By G. V. Raynor. 531 pp. inc. subject and author indexes. London, New York, Paris and Los Angeles, 1959. Pergamon Press. 75s. net.

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We have now developed such a tool—called a Carbohm. It takes the form of a primary element and measures carbon potential much in the same way that a thermocouple measures temperature. As carbon flows in or out of the Carbohm its electrical resistance changes, these changes being picked up by the Microcarb Controller, which operates a relay regulating the flow of fluid to the furnace.

Thus the carbon you set on the Microcarb Controller is the carbon you get the control giving you the desired case depth and case structure, control being possible at any eutectoid figure. Steel pressings normally made in spring steel can be made in mild steel and homogeneously carburised to any preset content. Rolls Royce, Jaguar, Leyland, Sperry Gyroscope, Singer, etc., all use this method.

The attractive Microcarb control booklet will be sent to you with pleasure on request.

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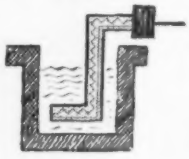
Resistance Heating – 2

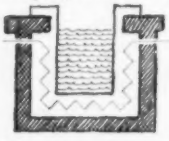
Electric resistance heating elements have been briefly described in Data Sheet No. 4, with two examples of their application in industry. This sheet lists some of the further applications which can be effectively dealt with by resistance heating.

Soft Metal Melting

Electric resistance melting is most commonly used for lead, tin, zinc, antimony, aluminium and their alloys—in processes such as tinning, type-casting, die-casting and lining bearings—at temperatures of up to around 800°C.



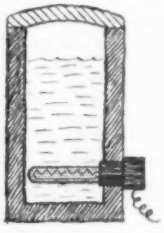
In most cases, sheathed elements are immersed directly in the metal, a more efficient method than applying heat to the outside of the containing vessel or pot. Immersion heating simplifies the application of lagging to the outside of the vessel, reducing heat losses and current consumption to a minimum. The elements are usually positioned near the inside wall of the vessel, leaving plenty of working space, but in a few cases, where the full volume of the pot is required, or where the metal to be melted is particularly corrosive, the elements are positioned outside the pot, often in contact with it.



In all cases, the precise temperature control that is so essential in soft metal processes is readily achieved by the use of electricity, and electric heating also leads to a reduction of casting rejects and metal wastage and a marked improvement in working conditions.

Liquid Heating

Electricity provides the ideal way of heating liquids such as water, oils, varnishes, plating, photographic and other solutions, and of melting and heating waxes and compounds, glues and pastes, tars and bitumen. Again, immersion heating is the method most commonly employed, but considerations of space or the nature of the liquid may sometimes necessitate the use of external heaters. Several types of devices are available to give precise and automatic temperature control, and lagging is again commonly applied to the vessel to minimise heat losses.

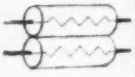


Fire hazards associated with inflammable liquids are invariably reduced by electric heating, particularly if immersion heaters can be used.

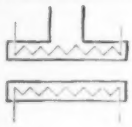
It is usually possible without difficulty to apply electric heaters, either immersion or external, to existing vessels.

Platen, Press and Roll Heating

Electricity offers the simplest and most convenient method of heating platens, dies and rolls. It gives the precise temperature-control characteristic of electric heating systems, with lower maintenance costs. Moreover, the relatively high temperatures required in some processes for maximum working speeds are reached without difficulty. Flexible electrical connections to moving parts give far less trouble than flexible pipe connections carrying hot water or steam.

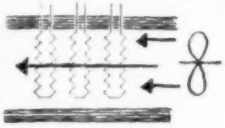


When electric heating is used, one or more presses can be operated without the necessity of keeping a boilerhouse staff at work.



Air Heating

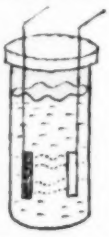
Streams of air, and of many other gases, can be heated most efficiently by electric resistance elements disposed across the duct leading to or from a fan. Heat is generated only inside the duct, just where it is required, and none is carried away through exhaust flues or pipes. Quick rise of temperature and precise temperature control are assured when electric resistance air heaters are used.



Electric Steam Boilers and Steam Raising

When steam is essential to a process, electrical steam raising can often be fully justified on economic grounds.

The means employed for bringing steam from a boilerhouse to the point of usage are often extremely wasteful, but where electricity is used the steam can be generated on the spot and losses from steam mains are eliminated. The efficiency of the electric boiler normally exceeds 96% and is practically constant at all loads, while the rapidity with which steam can be raised very largely eliminates banking losses.



Plant requiring process steam can be equipped with its own electric steam boiler, freeing the working space of steam mains just as individual electric motor drives free the factory of masses of shafting and belt drives.

Even where boilerhouse steam is still used, it is sometimes desirable for best results to boost the steam temperatures at the point of usage, to make up for transmission heat losses or to increase the superheat, and this function can most conveniently be performed by an electric resistance heater inserted in the steam line.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available – "Resistance Heating" is an example; "Induction and Dielectric Heating" is another.

E.D.A. also have available on free loan a series of films on the industrial use of electricity. Ask for a catalogue.

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LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
JUNE, 1959 Vol. LIX, No. 356

A High Intensity Cobalt Container for Industrial Radiography

NEWTON VICTOR, LTD., the X-Ray Department of Metropolitan-Vickers Electrical Co., Ltd., has recently supplied a cobalt container which, with a source of 1500 curies, is believed to be the most powerful in industrial use in the world. The container was taken to the Atomic Energy Establishment, Harwell, for the fitting of the cobalt 60 source, and from there it was transported by road to the Darlington factory of Whessoe, Ltd., to be housed in a specially constructed concrete building and used for the radiographic examination of welded seams in steel plate up to 5 in. in thickness.

This industrial cobalt container is the outcome of a number of years of experience with its medical counterpart. It is particularly suitable for work on large construction sites, especially if these are located in remote areas, as in addition to its inherent reliability it is largely independent of electrical and water supplies. Small currents are necessary for control purposes, but the quality of the radiograph is not dependent on the maintenance of precise voltages and frequencies. No water or oil cooling is necessary, and ambient temperatures up to 150° F. will not influence the operation of the container. Furthermore, its dust-tight, moisture-proof construction ensures its reliable operation in the most adverse site conditions, and in countries with wide extremes of climate.

The Steel Cylinder.—The protective container is housed in a steel cylinder which can be rolled on its heavy steel end-flanges over rough ground. A steel supporting fork is provided for slinging the unit from a crane or, with the angulating gear disengaged, for hauling the equipment up a loading ramp on to a vehicle. The unit is provided with 200 yd. of interconnecting cable.

Angulating Mechanism.—A worm wheel drive fitted to the fork is used to angulate the container, and thereby the beam of radiation, through 350°. Thus, when supported by a crane or other suitable mounting, the container can be rotated about both horizontal and vertical axes, and this is of particular value in the examination of spherical and cylindrical pressure vessels. The worm drive may be disengaged when the container is being moved to a new site.

The Protective Container.—The cobalt source is housed in a lead and heavy alloy protective container, thick enough to reduce the intensity of the radiation at the surface to 6·25 milli-roentgens per hour with a source of 1500 curies. In some systems the source is moved manually from the 'protected' to the 'exposure' position, and this is liable to involve friction and adhesion problems, as minimum clearances are necessary to avoid radiation leakages along the joints of the sliding arrangement. In the Newton Victor unit, the source is housed at the periphery of a disc which moves through 180° from the 'protected' to the 'exposure' position. Adequate clearances are possible without any loss of protection, as the source wheel is, in all positions, totally surrounded by the lead and heavy metal protective shield. The source wheel is driven by a motor against a mechanical stop, eliminating the wear and inaccuracy of latching contacts. A magnetic clutch between the motor and the source wheel ensures its immediate return by means of a lightly loaded spring if the electricity supply is interrupted.

The cobalt container and its control panel.

Interchangeable diaphragms of tungsten copper alloy provide a beam of radiation 6 in. or 12 in. wide × 5 ft. long (15 or 30 × 150 cm.) at a distance of 12 ft. (360 cm.) from the source. During the setting up of the container, a simple but powerful light projector is used to indicate the position of the beam on the specimen at distances up to 20 ft. (600 cm.). The light, in the form of a cross, indicates the exact position of the centre of the beam of gamma radiation. When not in use the projector may be swung out of the way, or, for transportation, completely detached.

The Control Unit.—The sheet steel control box for wall or desk mounting is 20 in. long × 12 in. wide × 11 in. deep (51 × 30 × 28 cm.) and includes the exposure timer, shutter control, signal lamps, master switch with removable key, and 150 ft. (45 m.) of 3-core cable.

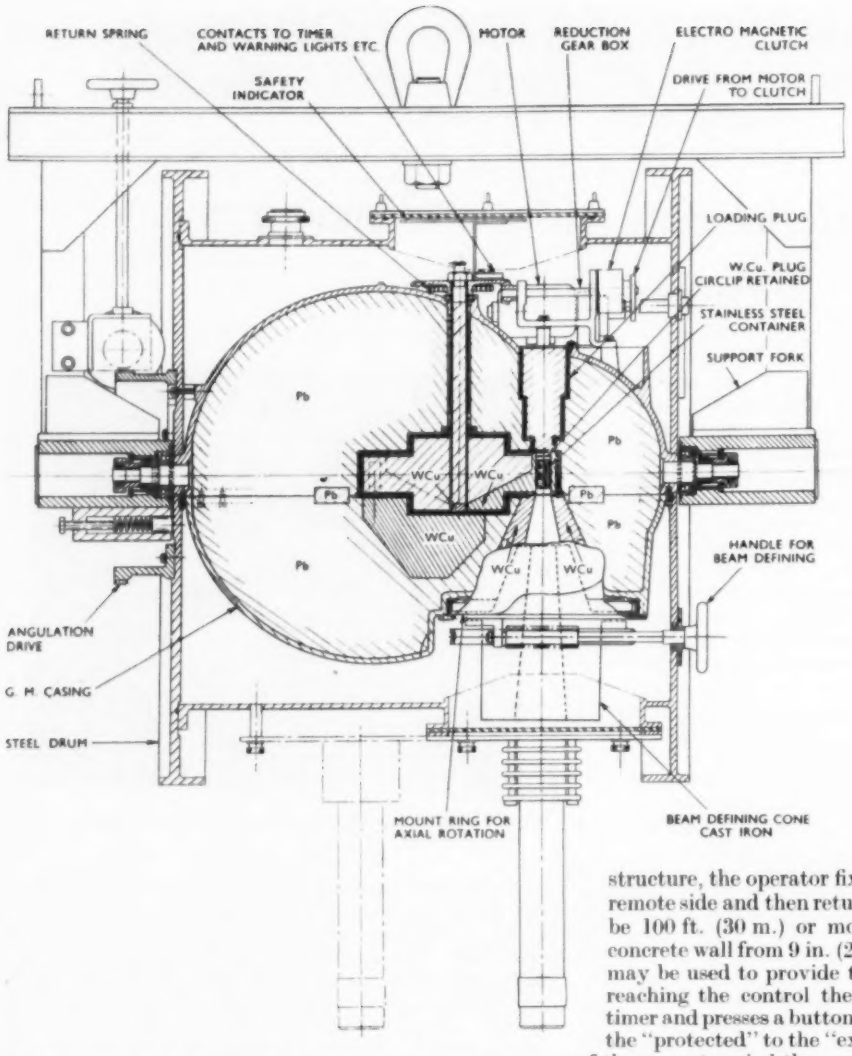


Diagram of the container showing the use of lead and tungsten copper for purposes of protection.

An exposure is initiated by pressing a button; the source moves from the 'protected' to the 'exposure' position and starts the synchronous motor timer which has a range of one second to 55 minutes in steps of one second. Signal lamps indicate the position of the source at all times; these red, green and amber lights are energized at a low voltage to show that all three lamps are in order. As one lamp at a time is energized at the full voltage, it indicates the position of the source; green indicates the source in the 'protected' position, amber the source moving from one position to the other, and red the source in the "exposure" position. Four red lamps on the container itself are also energized when the source is in the "exposure" position. All signal lamps may, in the event of power failure, be operated by long-life batteries included in the control system.

Operator Protection.—As described above, operator protection is assured while moving the source to the "exposure" position. Having positioned the container and adjusted the beam to the desired part of the welded structure, the operator fixes the film or cassette on the remote side and then returns to the control, which may be 100 ft. (30 m.) or more away. Alternatively, a concrete wall from 9 in. (23 cm.) to 36 in. (90 cm.) thick may be used to provide the requisite protection. On reaching the control the operator sets the exposure timer and presses a button which brings the source from the "protected" to the "exposure" position. At the end of the pre-set period the source is automatically brought back to the "protected" position; this also happens if at any time the electricity supply is interrupted. Additional signals and interlocking relays to prevent unauthorized entry to the exposure area can be easily connected to the control. Operators can, therefore, work continuously with this container without any risk of receiving an excessive dose of radiation.

Southern Instruments, Ltd.

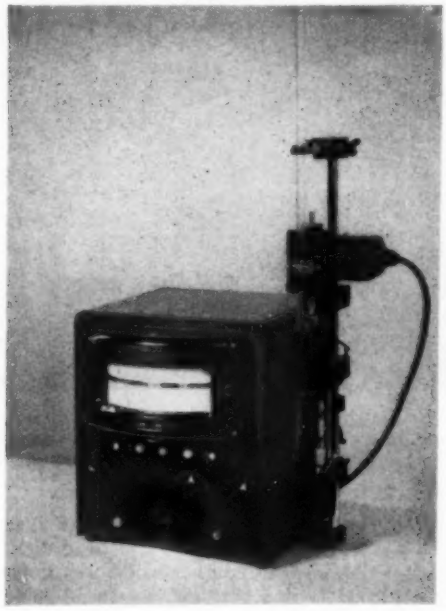
SOUTHERN INSTRUMENTS, LTD., of Camberley, Surrey, has associated itself with the Ampex Corporation of America and its U.K. subsidiary, Ampex Electronics, Ltd., in the manufacture and marketing of Ampex tape instrumentation equipment in Great Britain. The recently extended Southern Instruments factory at Camberley, which traditionally produces a wide range of precision electronic instruments in the recording, data handling, measurement and analytical fields, now also has the Ansafone telephone answering and recording machine in full-scale manufacture.

Exhibits of Metallurgical Interest at the Physical Society's Exhibition

The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception, and in this issue we continue a short series of reviews in which such items will be described.

Automatic Titrimeter

THE automatic titrimeter shown by Doran Instrument Co., Ltd., was designed for use with the Doran standard *p*H indicator which has ranges of 0–10 *p*H, 4–14 *p*H, and ± 0–1,000 mV., together with a high input impedance suitable for use with the normal calomel electrode system. The *p*H indicator circuit employs a matched pair of valves in a bridge network which, with careful stabilisation of the H.T. voltage, renders the reading of the test solution value independent of moderate changes of mains input voltage. The



Courtesy of Doran Instruments Co. Ltd.

Automatic titrimeter

application of the E.M.F. from the test cell causes a deflection of the controller indicator proportional to the *p*H or mV. value of the test cell.

Operation of the two relays associated with the two control indexes is used to regulate the addition of reagent to the test solution. Provision is made for the remote manual operation of the burette by " fast " and " slow " push buttons which enables complete titration curves to be plotted. Titrations involving rising or falling values of *p*H or mV. may be performed, the range of anticipation of the end point, i.e. the changeover from fast to slow reagent addition, may be adjusted from zero to a possible maximum of about 1·5 *p*H or 150 mV.

A single solenoid-operated valve is used for reagent addition, the flow through the valve being either " fast " or " slow " according to the setting of the controller. The slow flow may be adjusted by means of a screwdriver slot control between a maximum of approximately 5 ml./sec. and a minimum of 0·02 ml./sec. The accuracy of measurement is 0·1 *p*H or 10 mV., according to the range in use, but greater accuracy is possible by " buffering " the electrodes with a buffer solution of a value near that of the required end point. A variable speed stirrer is provided to ensure thorough mixing of the test solution and reagent, and reproducibility of titrations is of the order of ± 1 drop.

The solenoid-operated valve, burette and stirrer motor are mounted on the side of the instrument case, together with the electrode system, the test solution being contained in a 250 ml. beaker.

Stereoscopic Microscope

The Multimax stereoscopic microscope shown on the stand of R. & J. Beck, Ltd., provides the user with instant access to a wide range of magnifications (× 5 to × 160), the changeover being effected without altering the working distance. The feature rendering this possible is a rotating drum in which there are three pairs of specially computed objectives, so mounted that

Courtesy of R. & J. Beck, Ltd.

Multimax stereoscopic microscope

a genuine stereoscopic viewpoint is achieved in each position of the drum. The latter is rotated by means of large milled knobs, and the magnifications for each position are shown by engraved figures which appear in a window adjacent to the right hand knob.

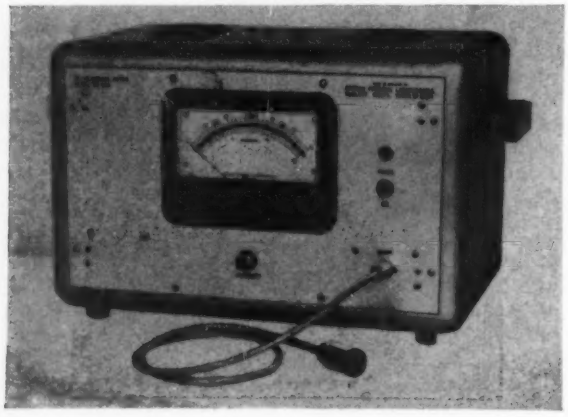
By placing the main limb and focusing slide beyond the viewing area, greater freedom for hand movement and access to the object is achieved. An incident lighting unit employing the 6V., 15W., prefocus lamp is available, carried on a fully adjustable arm which can be attached on either side of the limb. A focusing unit is incorporated to control brilliance and size of field for use with different magnifications, and the lamp brilliance can also be controlled by a rheostat on the transformer. For the examination of deep recesses, where the light is required to project perpendicularly down on to the object, a reflector is supplied which is used in conjunction with the lamphouse.

The fixed member of the main focusing slide provides a fitting enabling the microscope to be accommodated on a number of stands. The simplest of these consists of a large metal base plate, 18 cm. square, with a clear central circular aperture 10 cm. diameter. Glass or metal inserts are provided and with the former the subject may be illuminated from beneath by standing the base on a box containing a 60 W. lamp. A stand is made to facilitate the examination of large objects: the range of movement is about 8 in. vertically and 12½ in. horizontally. Full provision is made for moving and tilting the binocular head, and clamps are provided to the different adjustments.

A number of new adjuncts to the Multimax are in course of preparation: these include a gliding stage, drawing apparatus, heat absorbing and blue filters for the incident illuminator, eyecups, etc.

Tin Plate Thickness Meter

The tin plate thickness meter (Type TM.1158) featured on the British Physical Laboratories' stand is designed to cover 4 oz., 8 oz. and 12 oz. tin plate thicknesses, and is based on a design by the British Iron and Steel Research Association. The probe of the instrument, which is applied to the tin plate under test, utilizes the change in inductance and "Q" value of a coil when that coil is brought near a ferrous material. In this application the ferrous material is coated with tin. The coil forms part of a resonant circuit which is injected with a frequency of 4 Mc./s. This particular frequency is chosen to render the tin thickness indications independent of base metal thickness. The output from the resonating circuit is amplified and is indicated on a 5 in. scale length meter. Calibrated in microns, the maximum full scale deflection is 45 microns.

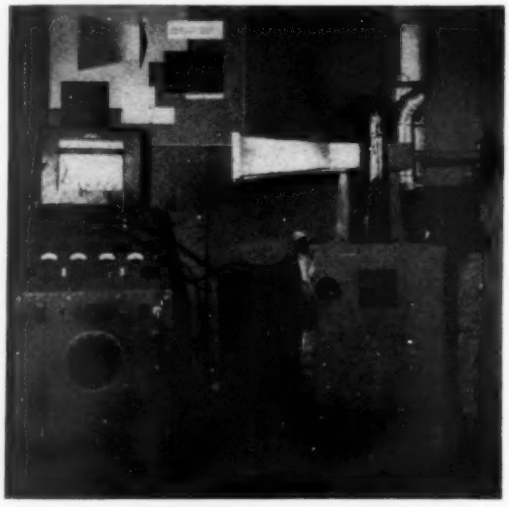


Courtesy of British Physical Laboratories, Ltd.

The T.M. 1158 tin plate thickness meter

Sand Testing Apparatus

High frequency dielectric heating equipment, designed and constructed by the British Cast Iron Research Association to obtain stress-strain curves on dried compression test pieces of moulding sand at elevated temperatures, was to be seen on the stand of the Department of Scientific Research. The machine is also capable of recording expansion curves on test pieces of the size used for physical tests.



Courtesy of The British Cast Iron Research Association

High frequency dielectric heating equipment and testing unit used to obtain the properties of moulding sand at high temperatures

Dielectric heating is used because sand is a poor conductor of heat, and when a test piece of dimensions suitable for obtaining strength and deformation values is placed in a heated furnace, a considerable time elapses before a uniform temperature is attained within the test piece. During the long heating period, any organic matter in the sand is destroyed and the clay modified. Very rapid heating throughout the test piece is necessary to simulate the condition on the surface of a mould being filled with molten metal.

The testing equipment is designed to show differences in brittleness of fracture of the specimen, in addition to the stress-strain properties to maximum stress.

Society Medal Award

THE SOCIETY MEDAL OF THE SOCIETY OF CHEMICAL INDUSTRY, which is awarded not more than once every two years for conspicuous services to applied chemistry or to the Society, has been awarded for 1959 to DR. F. H. CARR, C.B.E.

Conference on X-Ray Analytical methods

A conference will be held on X-Ray Diffraction and Spectrography in conjunction with the Department of Chemistry at Imperial College of Science and Technology, London, S.W.7; from Monday, 6th of July to Friday, 10th of July, inclusive. The conference will discuss and evaluate modern techniques and instrumentation for Diffractrometry and Fluorescent Analysis. An extensive range of modern equipment will be available for demonstrating the principles of these methods over a wide field of applications.

Time will be made available for the consideration and study of samples submitted by members. Sample preparation and presentation together with the use made of electronic analytical information will be discussed in relation to the requirements of industry.

Full information concerning the conference together with detail of registration fees may be obtained from the Conference Secretary at Research and Control Instruments Limited, Instrument House, 207 King's Cross Road, W.C.1, to whom all enquiries and applications should be addressed.

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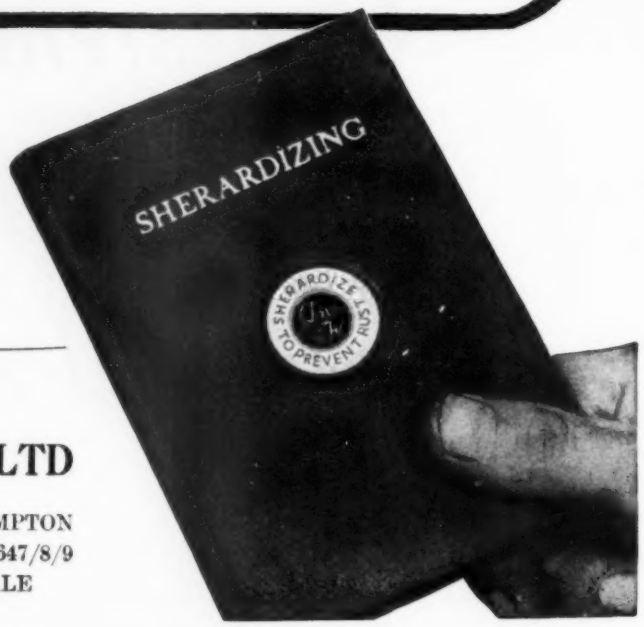

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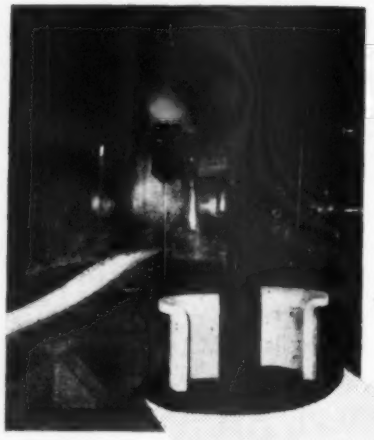

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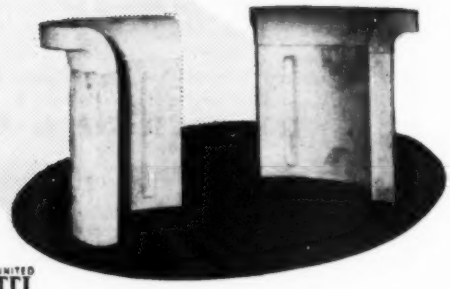

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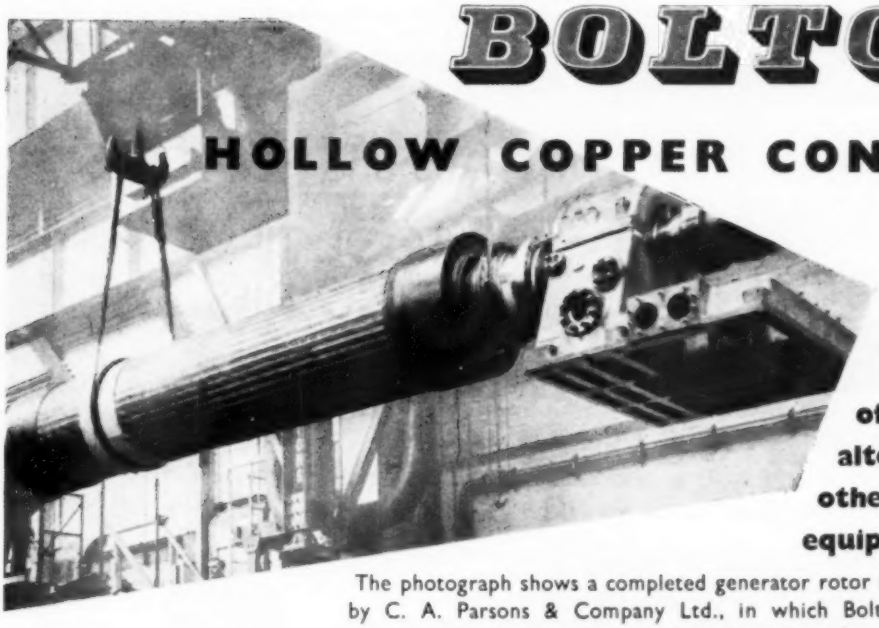

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Photograph by courtesy of C. A. Parsons & Co. Ltd.,

The photograph shows a completed generator rotor manufactured by C. A. Parsons & Company Ltd., in which Bolton's hollow copper conductors have been used in the end windings. The rotor is being removed from the high speed generator which is part of a 200 MW cross-compound turbo-generator for the Richard L. Hearn generating station, Toronto, Canada.

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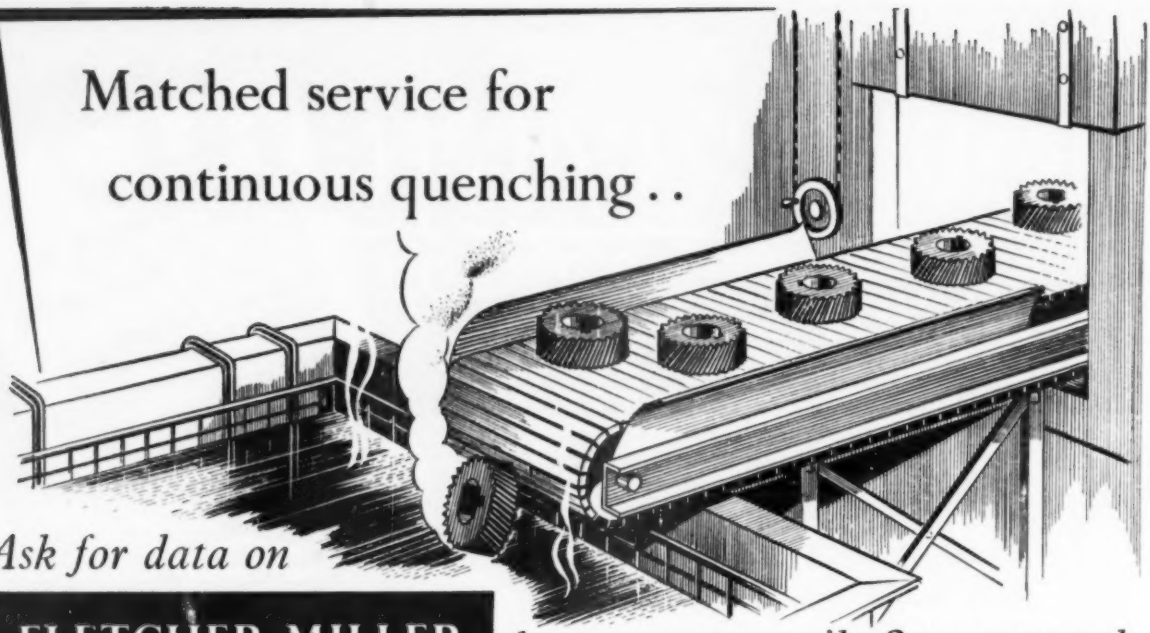

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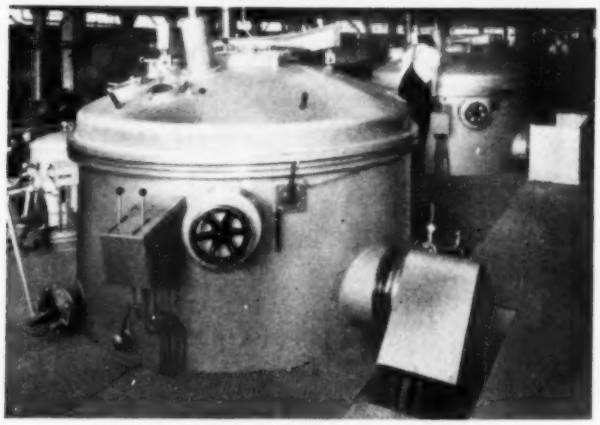

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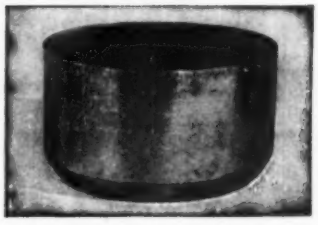

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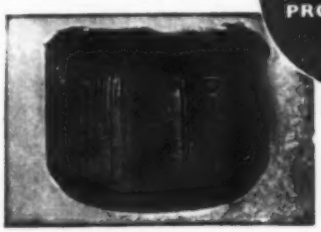

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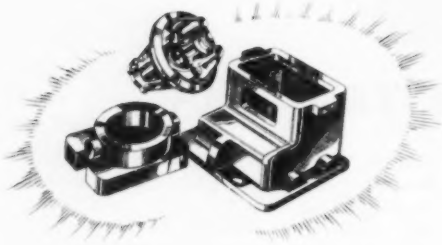

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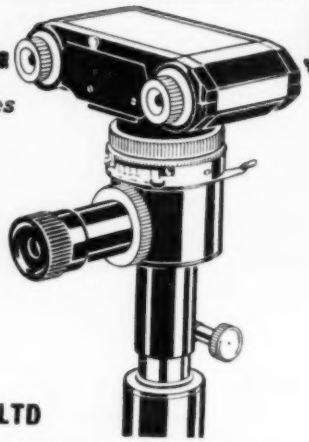

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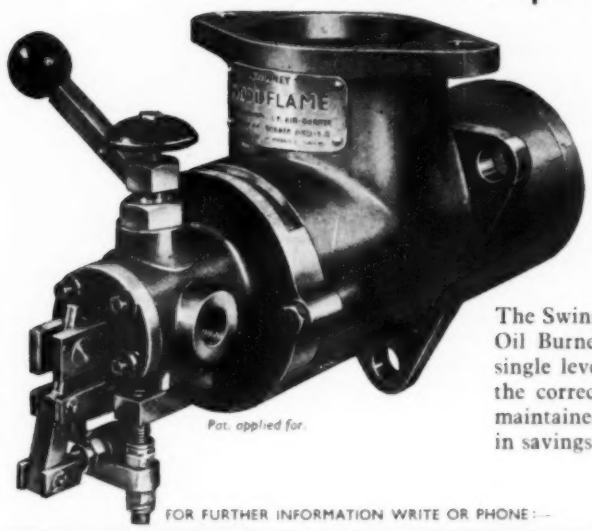

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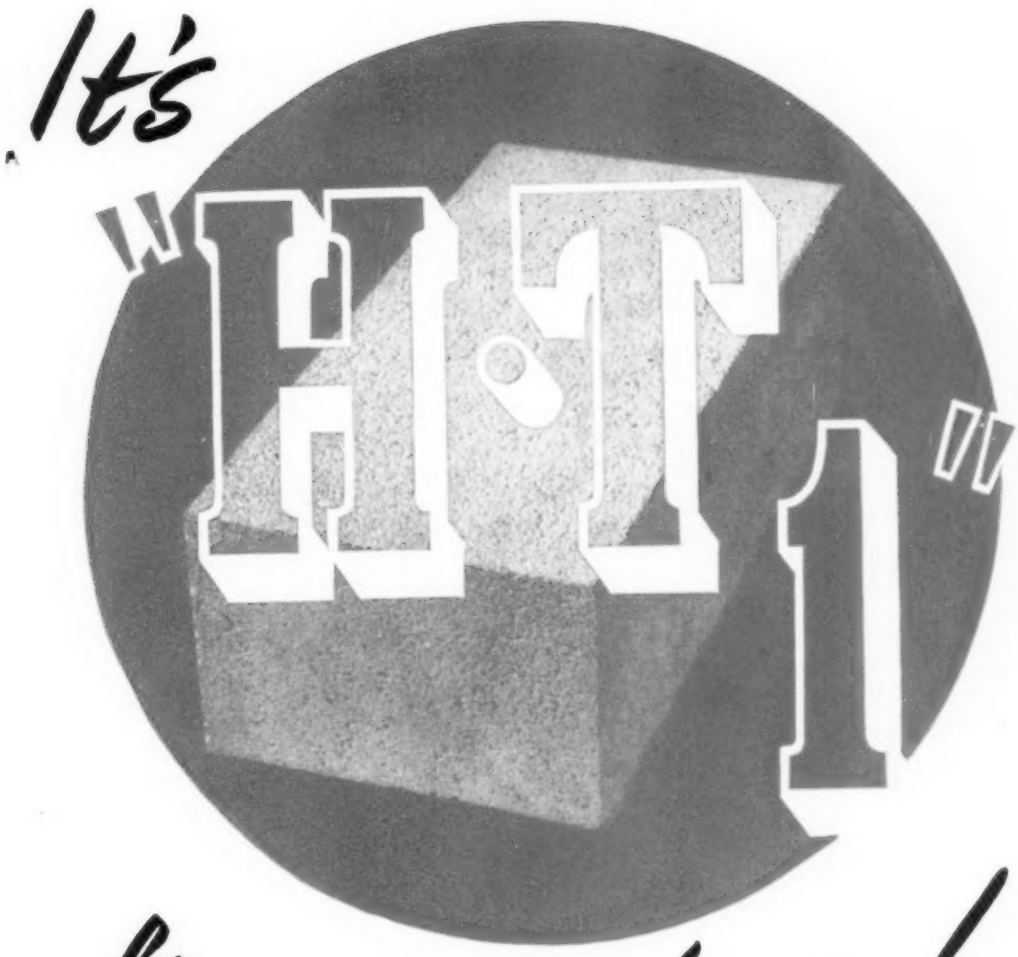

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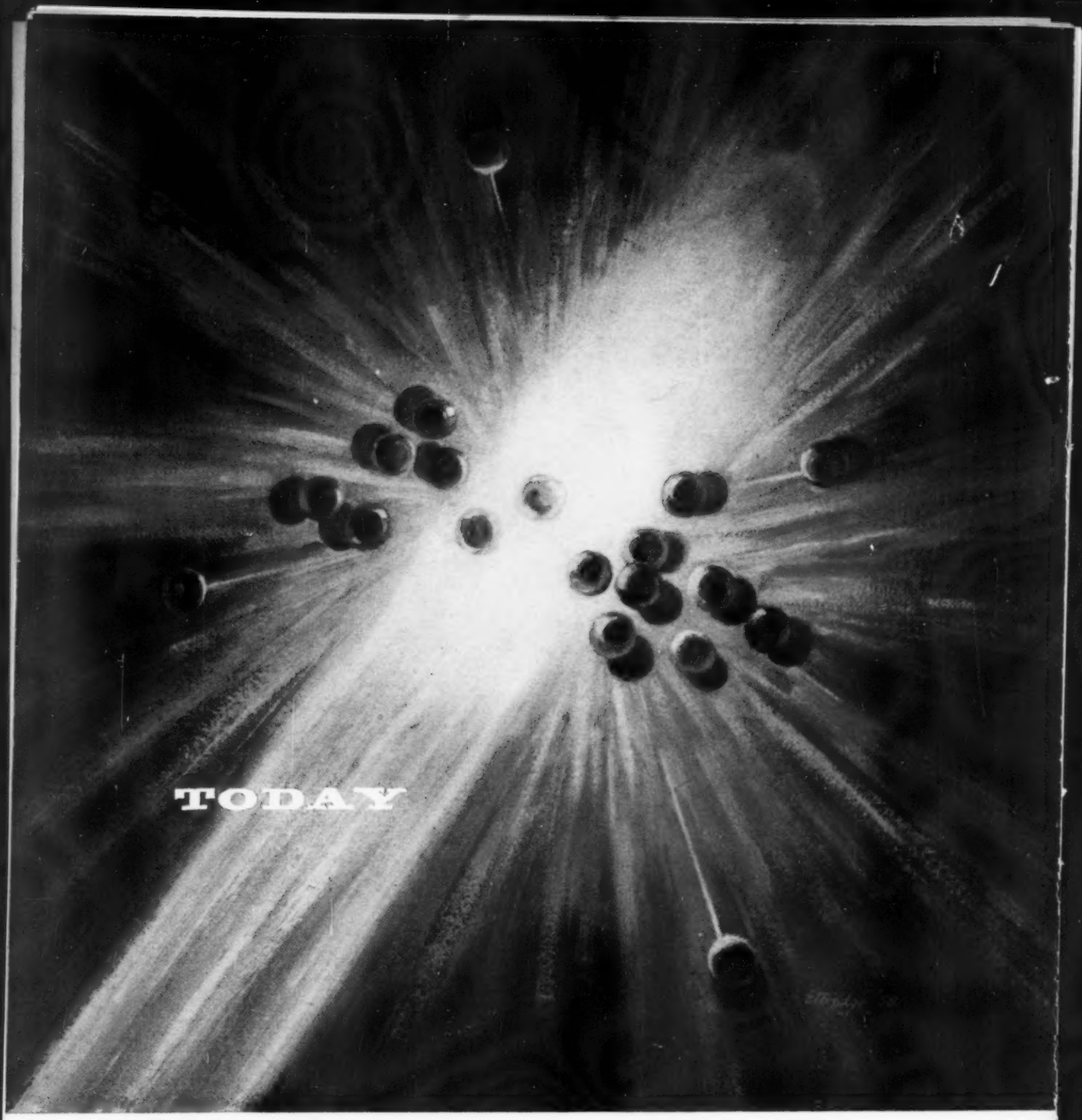

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